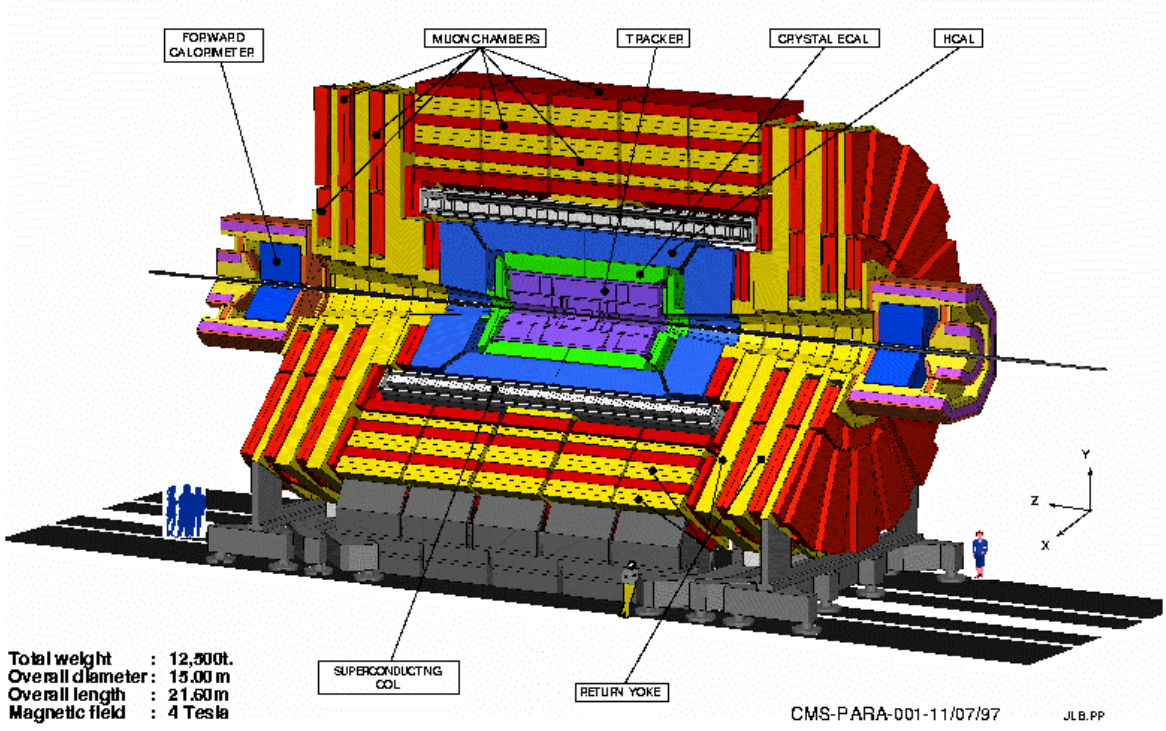
US CMS
Project Management Plan

November 1998



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US CMS Project Management Plan

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Section 1

Introduction

1. Introduction

This Project Management Plan sets forth the plans, organization, responsibilities, and systems for managing the work necessary for successful completion of the US Compact Muon Solenoid (CMS) construction project. Fermilab will provide management oversight for this project. This management oversight role is assigned to the Fermilab director, and thence to his designee, the deputy director, for detector and experimental program oversight. The project includes the construction of elements of the CMS detector for which the US groups collaborating on CMS take responsibility. A US CMS Project Office has been formed and has been charged with meeting the technical, cost, and schedule objectives of the US CMS Project. The project has its management office at Fermilab, in Batavia, Illinois. Fermilab is a DOE Laboratory operated under contract DE-AC02-76-CH-03000 by Universities Research Association, Inc. (URA). DOE, NSF, Fermilab, and the US CMS Collaboration will work as a team to accomplish the US CMS Project.

The US CMS Collaboration will participate in building the Compact Muon Solenoid (CMS) experiment, designed to study the collisions of protons on protons at a center of mass energy of 14 TeV at the Large Hadron Collider (LHC) at CERN. To enable studies of rare phenomena at the TeV scale, the LHC is designed to operate at a luminosity of 10^{34} cm^{-2} s^{-1}. The physics program includes the study of electroweak symmetry breaking, investigation of the properties of the top quark, searches for new heavy gauge bosons, probing quark and lepton substructure, looking for supersymmetry, and exploring for other new phenomena.

The US CMS Group agrees to take leadership responsibility in the CMS experiment for the endcap muon system, and for all hadron calorimetry, as well as for associated aspects of the trigger and data acquisition system. The US CMS Collaboration also plans to work on important areas of electromagnetic calorimetry, tracking, and common projects. These common projects will be provided as in-kind contributions whenever possible.

1.1. US CMS Project

The US CMS Collaboration is part of the CMS Collaboration (operating under the CMS Constitution) of high energy physicists from many nations. The CMS detector is designed to exploit the full range of physics at the LHC up to the highest luminosities.

Besides its responsibility noted above, for constructing the endcap muon system and hadron calorimeter system, US CMS groups will also take responsibility for parts of the CMS trigger/data acquisition, electromagnetic calorimeter, and forward pixel tracking. The US will design the endcap steel, which will be constructed as a CMS common project. The hadron calorimetry is managed by US groups. The US groups will build the barrel, supply the endcap transducers and front-end electronics, and build half of the forward system while maintaining complete hadron calorimeter management responsibility. In addition, since the hadron calorimeter is supported by the solenoid cryostat, US groups are involved in the design of the cryostat and intend to construct elements of it as a CMS Common Project.

For the other subsystems, the US responsibilities are not global. However, in every case they are focused on a particular area of US expertise. For example, US groups have overall CMS trigger management responsibility and will furnish essentially all endcap muon level 1 triggers,

all calorimeter level 1 triggers, the event builder switch, and the Data Acquisition output filter units. In EM calorimetry, the US CMS is responsible for transducers, front-end electronics, and monitoring. In tracking, the US groups will build all the endcap silicon pixels.

1.2 Project Management

The Project Management Plan presents the top level technical, cost, and schedule baselines for the US CMS Project, and sets forth the organization, systems, and plan by which the project participants will manage the US CMS Project. The line of authority at the top levels of the US CMS Project is shown in Figure 1.1.

The management approach described here is based on Office of Science and NSF experience with projects to construct complex detectors. It incorporates new features designed to address the unique challenges that result from joint agency sponsorship, funding caps, and the scale of the international collaboration. Three fundamental principles underlie the development of the organizational structure, the assignment of roles and responsibilities, and the implementation of management systems to optimize the success of the project. These principles are:

- The US CMS technical director and the construction project manager are jointly appointed by DOE, NSF, and Fermilab with input from the US CMS Collaboration. The US CMS Technical Director has the technical responsibility for the successful achievement of the performance goals while working closely with the Construction Project Manager who has responsibility to complete the project within the cost and schedule objective.
- Relevant formal management systems and requirements are implemented to aid in achieving the project goals and to account properly for the use of public funds. Fermilab has management oversight responsibility for the US CMS Project. To accomplish the oversight function, Fermilab will convene a Project Management Group, which will act as a high-level change control board for the US CMS Project.
- DOE, ER, NSF, Fermilab, and US CMS share the common goal of successfully completing the US CMS project and will openly communicate issues and work jointly to solve problems.

Following this introduction, Section 2 provides an overview of the design goals, scope, and objectives of the US CMS Project. The roles and responsibilities of the major project participants are defined in Section 3. Sections 4 through 7 describe the work and its organization and the associated cost, schedule, and technical baselines. A discussion of the system that will be used to manage and control cost and schedule and to measure the technical performance of the project is given in Section 8. Reporting requirements and review procedures are described in Section 9.

This plan will be reviewed and revised, as required, to reflect new project developments and other agreements among the participants. Revisions, as they are issued, will be signed by all participants, and will supersede in their entirety previous editions. To the extent that there are inconsistencies or conflicts between this plan and the terms and conditions of applicable laws, regulations, and contracts, the provisions of those documents shall prevail over this plan.

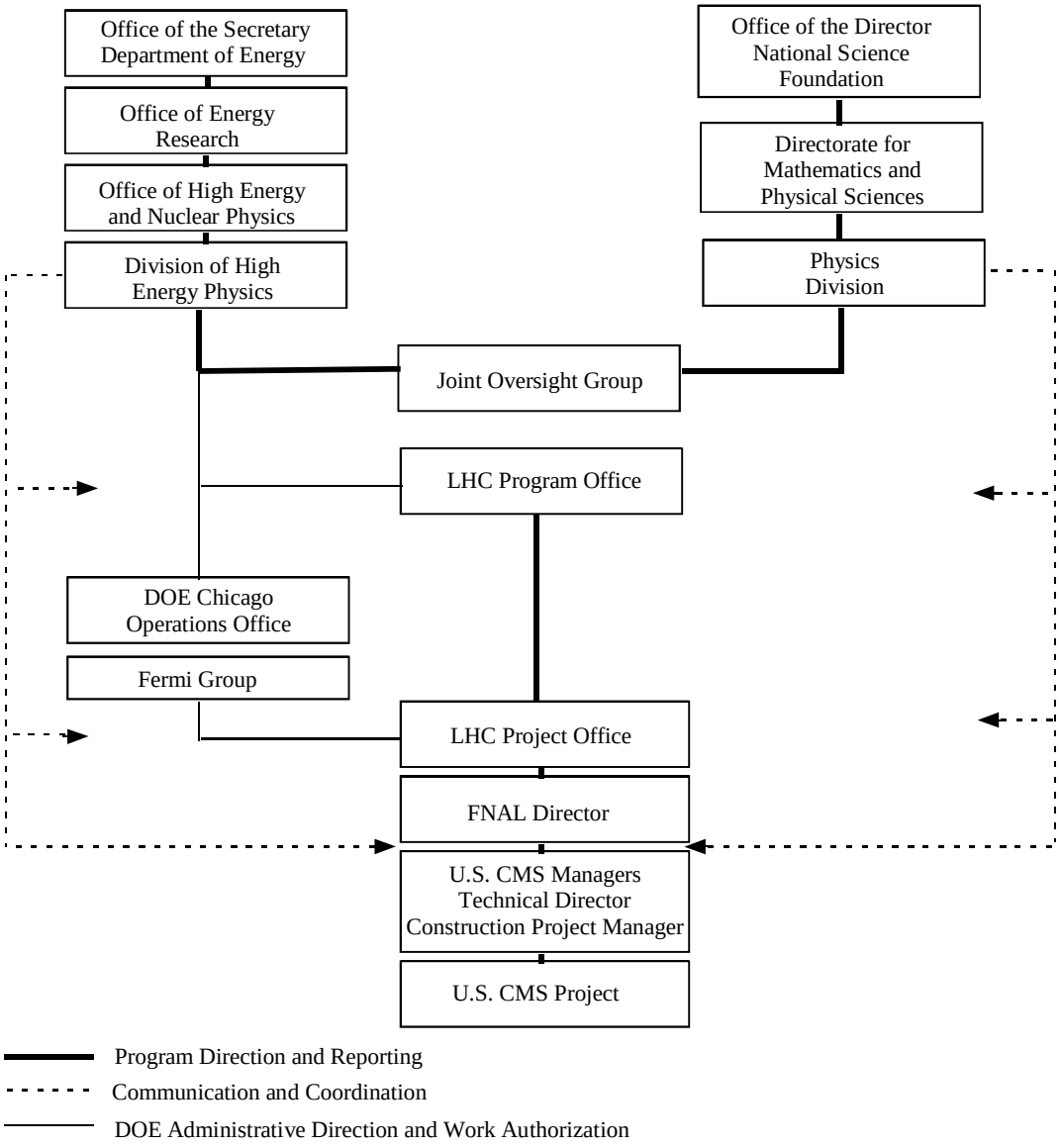


Fig. 1.1: Line of Authority at the Top Levels of the US CMS Project.

Section 2

Project Objectives

2. Project Purpose

2.1 Project Objective

The purpose of the US CMS Project is to construct the elements of the CMS detector for which the US groups collaborating on CMS take responsibility. Successful construction will enable high energy physicists to participate in research at the high energy frontier available at the Large Hadron Collider.

The US CMS project is described in the US CMS Letter of Intent of September 8, 1995 and in the US CMS Project Status Report of October 15, 1996, and is outlined below. US responsibilities within CMS include both management and construction.

US groups have management responsibility for the endcap muon system, the hadron calorimeter, and the trigger. Construction responsibilities within the US extend to portions of all five CMS subsystems: Muon, Hadron Calorimeter, Trigger/DAQ, Electromagnetic Calorimeter, and Tracking. In addition, there is US participation in the Common Projects. The costs of the Project Office at Fermilab are explicitly called out. Hence, there are seven work breakdown structure level 2 categories, as discussed in Section 5.

2.2 Technical Objectives

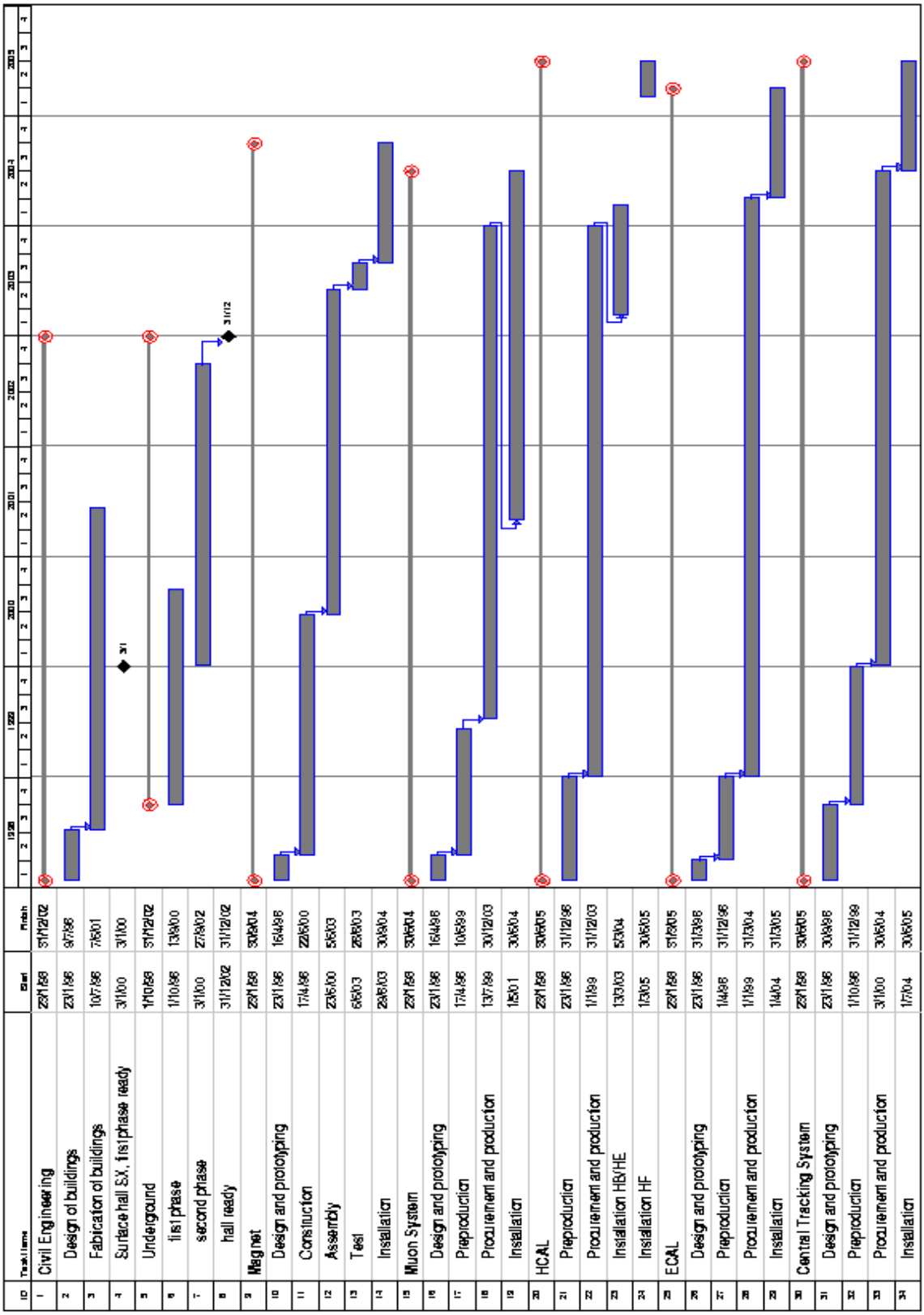
US CMS responsibilities in the muon system are for construction of the endcap muon chambers. US CMS responsibilities in the hadron calorimeter system are for construction of the entire barrel, the endcap transducers and readout, and roughly half of the forward system – concentrating on transducers and readout. US physicists also have responsibilities within the CMS trigger and data acquisition system. US CMS groups will construct the level 1 calorimeter and endcap muon trigger and the level 2 event builder switch and the output event filter. US CMS responsibilities in electromagnetic calorimeter are to provide some of the transducers, front-end electronics, and monitoring systems. The US groups involved in CMS tracking will provide all the forward pixel disks. A more detailed technical scope baseline is set forth in Appendix 2.

2.3 Schedule Objectives

The overall schedule for the project is shown in the CMS Construction Schedule, Fig. 2.1. This schedule must be supported by the US CMS Project schedule in that the US groups are responsible for a subset of the experimental apparatus. Both the U.S. schedule and cost are, of course, dependent on the rate of funding. This schedule results from discussions between CERN, CMS, DOE/NSF, and US CMS. A more detailed schedule is given in Section VI. The schedule is derived from, and is consistent with, the overall CMS planning. The schedule baseline is presented in the form of milestones in Appendix 3.

2.4 Cost Objectives

The Total Project Cost for construction of the US CMS Project is $167.2M in then-year dollars. The cost baseline is presented in Appendix 4: US CMS Cost Baseline. The cost baseline is based on detailed cost and contingency estimates. The technical scope baseline will be completed within the TPC. Should cost performance on the initial technical scope prove favorable, additional items may be added to the scope.


CMS Construction Schedule
27 April 1998

Section 3

Project Organization And Responsibilities

3. Project Organization and Responsibilities

3.1 Introduction

The US CMS Project operates within the context of the CMS collaboration, an internationally funded experiment located at CERN. The CERN management has ultimate responsibilities for CMS, and CMS reports to it. The executive function in CMS is provided by the CMS Management Board. The CMS Management Board is advised on technical matters by the Technical Board and on financial matters by the Finance Board.

The organization of the full CMS Collaboration is described in the CMS Constitution of September 13, 1996. Within CMS, the US CMS Collaboration acts congruently with a governance described in "The US CMS Constitution," August, 1997. Copies of these documents reside in the US CMS Project Office Records Repository. The DOE and NSF have jointly negotiated and signed an agreement and protocols with CERN for US participation in construction of the LHC accelerator and in the international collaborations for construction of the ATLAS and CMS detectors that will carry out the LHC scientific program.

Elected representatives of the US CMS Collaboration include a Spokesperson and an Executive Board. These entities represent the US CMS Collaboration in interactions with the formal US CMS Project. As a US Project, US CMS is financially responsible ultimately to DOE and NSF which are, in turn, responsible to the U.S. Congress. The remainder of this chapter focuses on the project aspects of the US CMS project.

3.2 Department of Energy and National Science Foundation (NSF)

Department of Energy and National Science Foundation are the funding agencies for the U.S. CMS Project. As such they monitor technical, schedule, cost, and management performance for the project.

The DOE has delegated responsibility for the U.S. CMS Project to the Office of Science, Division of High Energy Physics. The NSF has delegated responsibility for the U.S. CMS Project to the Division of Physics, Elementary Particle Physics Program. The assigned divisions in DOE and NSF function together through a Joint Oversight Group.

This activity is carried out under the provisions of an International Cooperation Agreement between CERN and DOE/NSF signed on December 19, 1997.

3.3 Joint Oversight Group

The U.S. CMS Project receives funding support from both DOE and NSF. All the subsystems involve close collaboration between DOE and NSF supported groups. It is, therefore, essential that DOE and NSF oversight be closely coordinated. To that end, the DOE Division of High Energy Physics and the NSF Division of Physics have formed a Joint Oversight Group whose responsibilities are defined in a Memorandum of Understanding between DOE and NSF. The Joint Oversight Group will establish programmatic guidance and direction for the U.S. CMS Project, coordinate DOE and NSF policy and procedures, and oversee the project as described in the DOE-NSF Memorandum of Understanding and the U.S. LHC Project Execution Plan.

All documents approved by Joint Oversight Group are subject to the rules and practices of each agency and the signed Agreements and Protocols.

3.4 U.S. LHC Program Office

The LHC Program Office, led by the LHC program manager, will provide day-to-day program management and support for U.S. participation in the LHC. The LHC program manager receives direction from, and reports directly to the Joint Oversight Group. As the DOE has been designated "lead agency" for the U.S. LHC Construction Program, the LHC program manager will generally be a DOE employee appointed by the director of the DOE High Energy Physics Division, subject to the concurrence of the Joint Oversight Group. The associate U.S. LHC program manager will generally be an NSF employee appointed by the director of the NSF Physics Division subject to the concurrence of the Joint Oversight Group. The program manager and associate program manager are responsible for daily coordination of the joint oversight activities described in the MOU between DOE and NSF. They coordinate the needs of the U.S. CMS Project within Headquarters. Specific responsibilities of the U.S. LHC Program Office are defined in the U.S. LHC Project Execution Plan.

3.5 DOE, Chicago Operations Office

The DOE Chicago Operations Office has the contract management responsibility for Fermilab. The CH Fermi Group will be the home of the U.S. LHC project manager. The Fermi Group manager will delegate to the LHC project manager the authority for day-to-day implementation and direction of the project. The Fermi Group manager will provide support from Fermi Group staff when necessary and appropriate.

3.6 U.S. LHC Project Office

The LHC Project Office, led by the LHC project manager, will provide day-to-day DOE/NSF project management and support for the U.S. LHC projects. The LHC Project Office serves as the day-to-day contact for DOE and NSF on issues specific to each of the U.S. LHC Projects. The U.S. LHC Project Manager will be appointed by the Fermi Group Manager, subject to the approval of the Joint Oversight Group. Specific responsibilities of the LHC Project Office include:

- To review and recommend approval of project planning documents including the U.S. LHC Project Execution Plan and its attendant project management plans for each of the three U.S. LHC projects;
- To review and recommend approval of project baselines and evaluate project performance against such baselines;
- To implement procedures for baseline management and control and approve changes to Level 2 baselines and recommend changes or corrective action to Level 1 baselines;
- To approve contingency for the U.S. LHC projects within levels established in the project management plans;
- To define the expectations for the project management systems used by the U.S. LHC projects;
- To conduct regular reviews of the U.S. LHC projects and participate in collaboration reviews as appropriate and needed to carry out on-site management;

- To participate in and provide support for the U.S. LHC Program Office peer reviews and reviews by oversight committees;
- To maintain close contact with the participating universities and national laboratories to assist in expediting the activities of the U.S. LHC projects;
- To ensure compliance by the individual LHC Projects with DOE and NSF requirements, e.g., ES&H and contracting regulations;
- To identify and arbitrate unresolved issues within the individual project organizations;
- To prepare quarterly reports and such other reports on the status of the U.S. LHC projects for DOE and NSF management as required in the Project Execution Plan and applicable DOE and NSF requirements;
- To manage all of the project office documentation;
- To keep DOE and NSF management informed on significant project issues and events.

3.7 Fermilab Director

The Fermilab director has the overall responsibility to the Department of Energy and the National Science Foundation for the management oversight of the US CMS Project. The Fermilab director has delegated certain responsibilities and authorities to the deputy director. Management oversight concerns the scrutiny necessary to maintain the cost and schedule goals to achieve the agreed project scope. The US CMS Collaboration consults with the Director as part of the procedure for appointing the US CMS technical director and construction project manager. The responsibilities of Fermilab are further described in a letter of joint appointment from DOE and NSF to the Fermilab director, dated November 30, 1997.

3.8 Fermilab Deputy Director

The deputy director is responsible for management oversight of the project. The technical director and construction project manager report to the deputy director and he will ensure that their duties carried out effectively. The Fermilab deputy director concurs in the Memorandum of Understanding between CERN and US CMS and in the Memoranda of Understanding between US CMS and the collaborating institutions.

To implement the work plan for the project, Memoranda of Understanding with participating institutions are written assigning responsibilities and describing the work to be executed. The Project Management Plan, the cost estimate, the schedule, and the financial plan for the project require the approval of the Fermilab deputy director and DOE and NSF with the concurrence of CMS and CERN.

3.9 Project Management Group

In response to the Department of Energy's and the National Science Foundation's request that Fermilab exercise management oversight for the US CMS detector project, a Project Management Group will be convened by Fermilab. The deputy director chairs the Project Management Group, which meets as necessary to monitor the progress of the project. The Project Management Group will include members from Fermilab, US CMS, and the DOE/NSF Project Manager as an observer. The US CMS spokesperson is also a member of the Project Management Group, thus ensuring communication of scientific issues to the US CMS Collaboration. The Project Management Group also serves as a high level Change Control

Board. The Project Management Group receives the reports of the US CMS construction project manager. As noted above the deputy director chairs the Project Management Group. The deputy director, construction project manager and technical director prepare agendas for these meetings.

Oversight of the project is implemented in part through reviews. Along with providing routine interactions with project management the Project Management Group will identify actions and initiatives to be undertaken to achieve the goals of the project including the allocation of both financial and human resources. The Project Management Group will also function as the Baseline Change Control Board for the project.

3.10 US CMS Level 1 Managers (Technical Director and Construction Project Manager)

The US CMS construction project manager and the US CMS technical director are co-leaders of the US CMS project. As such, they serve as level 1 managers of the US CMS project whose office resides at Fermilab. They have duties, roles, and responsibilities that are distinct, as well as some that are held jointly as described below. The primary focus of the construction project manager is to complete the project within its approved scope, on budget, and on schedule. The primary focus of the technical director is to see to it that the project produces components that meet technical specifications. The technical director and construction project manager consult regularly, keep each other fully informed of actions taken, and serve as each other's deputies in those roles and responsibilities that are distinct. Each backs up the other when either is not available.

3.11 US CMS Technical Director

The US CMS technical director is the principal point of contact for scientific issues and the technical performance of the US CMS scope of work. The technical director ensures that the project's technical goals are appropriate and achieved.

The US CMS technical director provides programmatic and technical coordination for the US collaboration's effort to construct and commission the components for the CMS detector. This is outlined in the Experiments Protocol to the International Cooperation Agreement and specified in an international Memorandum of Understanding agreed to by all the participants involved in supporting the CMS project. The technical director works with CMS to determine the scope of the US CMS contributions to the CMS detector. Scope changes from the baseline follow configuration change control procedures specified in this plan.

The technical director assists in developing the integrated cost and schedule plan for the project and negotiates and approves the Memoranda of Understanding and annual Statements of Work which are based on the plan. These Memoranda of Understanding and annual Statements of Work will be consistent with the project scope described in Appendix 2, US CMS Technical Baseline Document, and with approved changes to this document. The technical director approves the annual budget request made to DOE and NSF, which is prepared by the construction project manager in a manner consistent with the cost and schedule plan. The technical director maintains the level 1 schedule, which interfaces with the CMS general planning.

3.12 US CMS Construction Project Manager

The US CMS construction project manager manages the US collaboration's effort to construct and commission components for the CMS detector, as outlined in the Experiments Protocol to the International Cooperation Agreement and specified in an international Memorandum of Understanding. He is the principal point of contact for all parties on the project management of the US CMS construction effort. The construction project manager is responsible for completing the construction project on schedule and within the approved funding and scope. The construction project manager is responsible for preparing the Project Management Plan and ensuring implementation of the management systems described in that document.

The construction project manager establishes and maintains an effective project organization to manage procurements, construction and commissioning of project components. He is responsible for allocation of resources assigned to the US CMS project. The construction project manager has fiscal authority for US CMS project funds and is responsible for monitoring expenditures of these funds as well as for tracking and reporting variances from baseline scope, schedule and cost estimates specified in the cost and schedule plan. The construction project manager is responsible for developing and presenting DOE and NSF the budget requirements for the project, consistent with the cost and schedule plan. He is also responsible for determining the allocation of the funds available, including contingency funds. The construction project manager has line management responsibility for Environment, Safety and Health for the US CMS project.

The construction project manager will develop an integrated cost and schedule plan and approves the Memoranda of Understanding and annual Statements of Work for the project.

3.13 Roles and Responsibilities of the Construction Project Manager and Technical Director

Either the technical director or the construction project manager may represent the US CMS project in interactions with CERN, DOE, NSF, Fermilab, and the collaborating universities. The technical director and construction project manager report to the director of Fermilab or his designee and through him to DOE and NSF. Both are appointed jointly by DOE, NSF, and Fermilab.

The construction project manager and the technical director each have authority to negotiate on behalf of the US CMS project with collaborating institutions and Fermilab for collaboration or laboratory resources and for their optimal utilization and management.

Either the technical director or the construction project manager may identify the need for project scope changes as they arise. When considering scope changes having significant impact on the physics capability of the detector, the technical director may receive technical advice from review committees. The technical director creates such committees as needed and appoints their members in consultation with the US CMS Executive Board and the CMS Management Board. Section 8 of this document describes the procedures for scope changes.

The technical director and construction project manager are responsible for organizing review presentations and status reports on the project in response to requests from the Fermilab director or the funding agencies. The construction project manager and technical director will initiate internal reviews of level 2 subprojects to ensure that subprojects are meeting technical performance, cost, and schedule milestones.

The construction project manager and technical director have the joint authority to appoint deputy and assistant managers and subproject leaders such as level 2 managers as described below.

3.14 Level 2 Managers

The WBS level 2 managers are appointed jointly by the US CMS technical director and construction project manager. The level 2 managers are members of the Project Management Group. They have specific responsibilities listed below:

- Define the WBS work scope
- Estimate work scope cost
- Schedule the work scope
- Time-phase cost estimate (integrate cost estimate to schedule)
- Determine schedule progress at the end of each month
- Validate earned value monthly for each active task
- Determine/validate monthly actual costs
- Evaluate monthly and cumulative-to-date budgets, earned value, and actual costs
- Accomplish analysis and take corrective action accordingly
- Analyze each month the cost and schedule variances provided by the project office
- Take corrective actions to meet technical, cost, and schedule baselines
- Plan and manage the design, construction, installation, and commissioning of their respective subsystem projects
- Serve as the cost/schedule managers for all WBS elements in their subprojects
- Participate in project planning
- Manage cost estimating for their subsystems
- Participate in project planning, scheduling, and assessing work accomplishments

3.15 Project Cost and Schedule Manager

Project cost and schedule manager reports to the construction project manager and is responsible for the operation of the project management control system including:

- Maintenance of the baseline cost estimate
- Maintenance of the baseline schedule
- Monthly update of project office schedule progress from the level 2 managers
- Monthly collection of project actual costs
- Production of monthly cost performance report

- Analysis of actual cost reports from the participating laboratories for correctness of charges
- Assistance to the project office and level 2 managers in budgeting.

3.16 US CMS Project Office

3.16.1 Fermilab as US CMS Host Institution

Fermilab has agreed to act as host laboratory to the US CMS Project, and will serve as the location of most project reviews. The US CMS Project Office is located at Fermilab, and will provide administration for DOE funds. (Administration of NSF funds is provided by Northeastern University; see below.) Fermilab will also provide Service Accounts for US CMS groups, as well as travel and purchasing support.

Use of Fermilab facilities and services shall be agreed upon via Memorandum of Understanding just as with the use of available infrastructure at any US CMS institution. The level 1 manager's report to the Fermilab deputy director to account for all resources provided by Fermilab to US CMS. The services may include services provided to the Fermilab CMS group or may be services provided to other US CMS institutions. Within the framework of the Memorandum of Understanding, specific items shall be negotiated annually by Fermilab (as host laboratory), by the US CMS technical director and construction project manager, and by the collaborating US CMS institutions. These specific items are incorporated in the annual Statement of Work.

3.16.2 Allocation of Funds

The construction project manager annually determines the allocation of funds to US CMS institutions with advice from the technical director. Subsequently, purchase orders are issued to those institutions (including Fermilab as a US CMS collaborating institution). Explicit arrangements are defined in the US CMS Memorandum of Understanding and annual Statement of Work, which appear in Appendix 1.

The organization of the US CMS Project Office is shown schematically in Fig. 5.1. The US CMS level 1 managers head this office. Allocations of project funds are the purview of the project manager with the scientific advice of technical director. All costs of the Project Office (exclusive of physicist salaries) shall be explicitly borne by the US CMS Project and are called out in the US CMS WBS.

3.16.3 Management Reserve and Funding Allocation

The construction project manager shall hold a management reserve each fiscal year. This management reserve is created by initially allocating amounts that leave sufficient budget authority for additional allocations throughout the year. That reserve will be committed by the construction project manager during the course of the year, based on performance and need of the various groups in the US CMS Collaboration. The reserve will be allocated to individual US CMS institutions in the same manner as the main fiscal year allocation.

3.16.4 Northeastern University

The Northeastern University Administrator of NSF Funds is a member of the Project Management Office of the US CMS Project as indicated in Figure 5.1. The Administrator of NSF Funds is responsible for administration, disbursement, and reporting of the use of NSF funds in accordance with the NSF cooperative agreement with Northeastern University. The Administrator is appointed by the NSF and serves as the NSF liaison on the CMS Finance Board. The Administrator is a member of the Project Management Group.

As a member of the project management team the Northeastern University Administrator of NSF Funds reports to the construction project manager and under his direction the Administrator arranges for the appropriate procurement instrument (e.g. Subcontract) to be issued from Northeastern University to the respective CMS participating institutions. Disbursement and utilization of funds provided by the NSF for US CMS are subject to this management plan and the configuration, change control, and reporting procedures herein defined. The annual Statement of Work describes a workplan for each institution that is consistent with the scope of the US CMS Project approved by the funding agencies. Subcontracts issued by Northeastern will authorize expenditures at the lowest level of the WBS in a manner consistent with the approved Statement of Work for each institution. The NSF funded institutions invoice Northeastern University by WBS activity. Level 1 manager approval is required before invoices are paid. Northeastern University will track procurements and invoice payment and report this information to the US CMS Project Office on a monthly basis.

3.16.5 Project / Collaboration Interactions

The US CMS Project personnel are a subset of the US CMS Collaboration who focus on constructing the US CMS Project scope portions of the CMS detector. As such the life of the project team spans only the construction period. The Collaboration continues during the use of the detector for physics research. Furthermore, the Collaboration arranges for the presentation of talks and papers at conferences and undertakes activities outside the scope of the project, such as offline computing.

As noted above the formal project / collaboration interaction is through the spokesperson and the Executive Board. The spokesperson is a member of the Project Management Group and is therefore well informed of progress and pending changes, so as to assure that scientific issues are communicated to the US CMS Collaboration.

3.16.6 Support and Programmatic Organization

The US CMS Project Office will draw on Fermilab resources as agreed by the Fermilab director. The use of these resources will follow procedures consistent with the Laboratory's current accounting, budgeting, human resources, ES&H, and procurement department policies. The Project will obtain support to the extent agreed from the Laboratory's indirect support group, including:

- Accounting and Budgeting
- Environment, Safety and Health
- Human Resources

- Legal and Material
- Facilities Management
- Quality Assurance
- Information Services

All support functions will be provided through the Laboratory organizational lines of authority and responsibility. The US CMS project manager will direct questions of priority need for Laboratory support through normal lines of authority to the Laboratory deputy director.

3.16.7 Review Committees

Review committees provide a means for the technical director and the construction project manager to review technical, cost, and schedule issues for level 2 subprojects. These committees may also review the physics performance of the subsystem or may recommend scope changes to construction project manager and technical director. Review committees are appointed from the CMS membership as required. The construction project manager and technical director charge them, in consultation with the Project Management Group. Reports and recommendations from review committees are transmitted to the level 2 managers and are in general made available to the entire US CMS collaboration.

3.16.8 Subproject Technical Committees

There may be technical committees associated with a subsystem and separate from the US CMS Review Committees discussed above. The level 2 manager, as needed, appoints them. Members of such technical committees advise the subsystem level 2 managers on technical directions, alternatives, and methods of performance. The members of the committee include scientists responsible for the design and fabrication of the subsystem or of major tasks within it, as well as other technical experts. The level 2 manager appoints the members of subproject technical committees. These committees act in an advisory capacity. Decision authority remains in the hands of the level 2 manager consistent with the line responsibility described above.

3.16.9 Project Communications

The US CMS Project necessarily entails coordination among CERN, Fermilab, DOE, and NSF. At the experiment level, CMS must coordinate with the US CMS collaboration. The US CMS Project involves DOE, NSF, CERN, Fermilab, CMS, and US CMS. For the project to progress, all parties need to be fully informed of current progress, plans, issues, problems, solutions, and achievements.

Communication among participants is free and informal to the maximum extent feasible. Notes, “drafts,” phone calls, electronic mail, and informal discussions are exchanged frequently among the participants to accomplish information flow, raise issues for mutual resolution, and explore the viability of plans and solutions. Distribution of copies of informal correspondence to all participants is desirable to keep them fully apprised of these communications. Each organizational participant should designate an individual to coordinate informal communications and to assure their proper distribution within that organization.

The World Wide Web is proving a valuable tool in providing up to date information to members of the collaboration and others. The web home pages for CMS and US CMS are http://cmsinfo.cern.ch/Welcome.html and http://uscms.fnal.gov respectively.

3.16.10 Educational Outreach

The education liaison function includes the development of educational proposals of US CMS. In support of these and other educational activities, the US CMS Project Office supplies funds for programmatic travel and for material and service supplies. A CMS Educational Outreach Person has been named. This person works with personnel from other laboratories and institutions to maximize the effectiveness of the educational outreach program.

Section 4

Work Plan

4. Work Plan

4.1 Introduction

The US CMS detector activities are briefly described in sections 2.1 and 2.2. The technical scope baseline is described in more detail in Appendix 2. This section describes the work plan for accomplishing the tasks required to provide the deliverables described in the technical scope baseline at CERN for incorporation into the CMS Detector.

4.2 Work Description

This project provides for the construction of elements of an experiment to be performed at CERN, designated the US CMS Project. This effort entails completion of a research and development program, conceptual design, detailed engineering and design, procurement of materials and services, fabrication of sub-detector elements, testing of components, assembly of components into sub-detectors, and installation of sub-detectors into the experimental cavern and assembly of the entire detector in the cavern.

The US CMS Project Organization described in section 3 of this document will carry out or oversee these activities. The research and development program was carried out primarily in FY 96 and 97. Technical design reports have been written and approved for six of the seven sub-detector elements included in the US CMS scope. A list of the major procurement items (costing more than $100K) has been compiled and includes the planned schedule for these acquisitions shown in Appendix 6. Staffing requirements at each of the participating institutions have been projected based on the agreed-upon scopes of work that they will perform.

4.3 Quality Assurance Program

Quality assurance is an integral part of the design, procurement, fabrication, and construction phases of the US CMS Project. Special attention is being devoted to items that will affect the performance capability and operation of the CMS detectors. The responsible person for technical specifications is the US CMS technical director.

It is the policy of the US CMS project that all activities shall be performed at a level of quality appropriate to achieving the technical, cost, and schedule objectives of the project. To implement this policy, the US CMS project will develop a standard quality implementation plan based on the quality assurance criteria established by DOE and NSF. The responsible person for the Quality Assurance Plan for the US CMS is the US CMS Construction Project Manager.

The US CMS project will follow a Specialty Quality Implementation Plan that will define the management policies in regard to 1) quality assurance program, 2) personnel training and qualification, 3) quality improvement, 4) documents and records, 5) work processes, 6) design, 7) procurement, 8) inspection and acceptance testing, 9) management assessment, and 10) independent verification.

Vendors will implement quality assurance programs appropriate to the services being furnished. As specified in the Memorandum of Understanding, US CMS activities at each institution will use the implemented quality assurance programs. All these programs, as well as

implementing procedures, are subject to review and audit by the US CMS Project Office at Fermilab.

4.4 Environment, Safety, and Health (ES&H)

Activities conducted at US institutions will follow the ES&H policies and procedures of those specific institutions. The annual Statements of Work signed between the institution and US CMS identify a responsible safety person for CMS activities at each institution.

Two large activities are taking place at Fermilab: construction of the endcap muon chambers and construction of the hadron calorimeter scintillating tile sandwiches. The muon chambers will follow the ES&H procedures of the Technical Division. The calorimeter sandwiches are being put together by the same group that recently completed the CDF end plug calorimeter and will carry on the CMS activities using the same Fermilab procedures used for CDF.

Finally, these components are being delivered to CERN to be incorporated in the CMS detector there. Therefore our designs will take into account the CERN safety specifications, procedures, and guidelines. Furthermore, CERN safety personnel including the CMS Group Leader in Matters of Safety and a member of Technical Inspection and Safety (TIS) commission will participate in critical (technical) design reviews of those items being provided by US CMS that have important safety ramifications. Appropriate TIS personnel approve the safety aspects of the designs.

Section 5

Work Breakdown Structure

5. Work Breakdown Structure

All work required for successful completion of the US CMS Project is organized into a work breakdown structure. The work breakdown structure contains a complete definition of the scope of the project and forms the basis for planning, execution, and control of the US CMS project. The US CMS work breakdown structure is extended to a sufficiently low level to make each deliverable and its provider unique and trackable. Specifically, the work breakdown structure provides the framework for cost estimating, scheduling, and budgeting.

The project summary work breakdown structure is a consolidation of the top three levels of the US CMS construction project work breakdown structure. The sample US CMS construction project work breakdown structure is as follows:

1	**Endcap Muon**
1.1	Cathode Strip Chambers
1.2	Electronics
1.3	Mechanical Structure
1.4	Installation
1.5	Slow Control
1.6	Services
1.7	Alignment
2	**Hadron Calorimeter**
2.1	Barrel Hadron Calorimeter
2.2	Outer Barrel Calorimeter
2.3	Endcap Hadron Calorimeter
2.4	Forward Calorimeter
3	**Trigger and Data Acquisition**
3.1	Trigger
3.2	Data Acquisition
4	**Electromagnetic Calorimeter**
4.1	Barrel Photodetectors
4.2	Electronics
4.3	Monitor
4.4	Crystal Development
5	**Forward Pixels**
5.1	Readout System
5.2	Sensors
5.3	Mechanical and Cooling
5.4	Final Assembly and Testing
5.5	Tests
5.6	Software

5.7 Project Management
5.8 Installation at LHC

6 Common Projects
6.1 Package A, Barrel Yoke and Vac Tank
6.2 Package B, Endcap Yoke
6.3 Package C, Superconductor
6.4 Package D, Coil Winding
6.5 Package E, CERN-Power, He Refrig, etc.
6.6 Package F, In Kind
6.7 Package G, Common Funds
6.8 Common Project Software

7 Project Office
7.1 Baselining
7.2 Tracking
7.3 Reporting
7.4 PO Support
7.5 NEU Administration
7.6 Programmatic Travel
7.7 Education

The levels of the work breakdown structure reflect the logical breakdown of the work required to complete the project. Lower levels provide greater detail. The number of levels is established by extending the description down to a level at which individual components (typically costing about $10k) can be identified and associated into a well-defined piece of equipment or structure.

The detailed activities to design, build, and commission the US CMS are described in the work breakdown structure dictionary and/or in the basis of estimates. Each element of the work breakdown structure has cost, manpower, and schedule associated with it and is the key element for planning and controlling cost and schedule.

Changes to parameters are controlled by a change control system. The impact of any such change on the associated cost, schedule, and WBS dictionary will be evaluated by the appropriate Change Control Board. The cost and schedule manager is responsible for maintaining the current cost, schedule, and dictionary, and the records of all changes. All changes must be approved at the appropriate level before implementation. Once approved, the changes will be incorporated in the work breakdown structure, work breakdown structure dictionary, baseline budget, estimate to complete, schedule, etc. as required.

5.1 Cost Estimating

The work breakdown structure supports a systematic approach to preparing the cost estimate for the project. The work breakdown structure is extended to a sufficient level of detail to allow definition of individual components for which a cost can be reasonably estimated. The budget and cost estimate are equal for the lowest level in each branch of the work breakdown structure when the baseline is approved.

5.2 Scheduling

The work breakdown structure also supports a systematic approach to preparing the project schedule. Again, each work breakdown structure element at the lowest level of the structure is assigned a duration. Establishing the interdependencies between the various elements creates the project schedule.

5.3 Budgeting

The schedule is then "resource loaded" by spreading the cost estimate over time to reflect the work plan. This provides each element of the work breakdown structure at the lowest level a budgeted "cost of work scheduled". The budget of the project can be seen at any level by performing a summary over contributing lower levels. Budgets are formal statements of the financial resources set aside for carrying out specific activities in a given period. Note:

- The budget reflects the US CMS financial plan, which represents the goals of the project management plan.
- The budget is expressed in time-phased quantifiable or measurable terms so that status along the way can be determined.
- All Level 2 components of the organization will be made aware of their portion of the overall budget.
- Performance against the budgets will be monitored and reviewed monthly with project management.

5.4 Work Breakdown Structure Support Requirements and Dictionary

The work breakdown structure, in conjunction with the associated resource-loaded schedule provides the framework for projecting funding and manpower requirements over the life of the project. The work breakdown structure level 2 managers are shown in Table 5.1. The level 2 managers are required to provide the construction project manager a detailed work breakdown structure dictionary of their subsystems. This dictionary and the basis of estimate provide the documentation, which defines the quality of the estimated costs for the project.

5.5 Performance Measurement

The work breakdown structure supports the monitoring, control, and reporting of cost and schedule performance. Since each element of the work breakdown structure, and by association each work element, has a well-defined budget and schedule, a view of the progress of the project at any level is available at any time. Comparison of the actual costs ("actual costs of work performed") and planned budget with the work performed, known as earned value ("budgeted cost of work performed"), provides the cost and schedule variances for current month, cumulative to date, and at completion.

5.6 Management Review, Corrective Actions, and Change Request

The detailed scope of the project is contained within the work breakdown structure and described in the work breakdown structure dictionary. After reviewing the status of their budget/actuals versus work accomplished to date, managers may need to take corrective actions

(i.e., descoping work, issuing contingency, etc.) to keep on an acceptable budget and scheduling path. Proposed changes to the scope can readily be evaluated within the WBS framework.

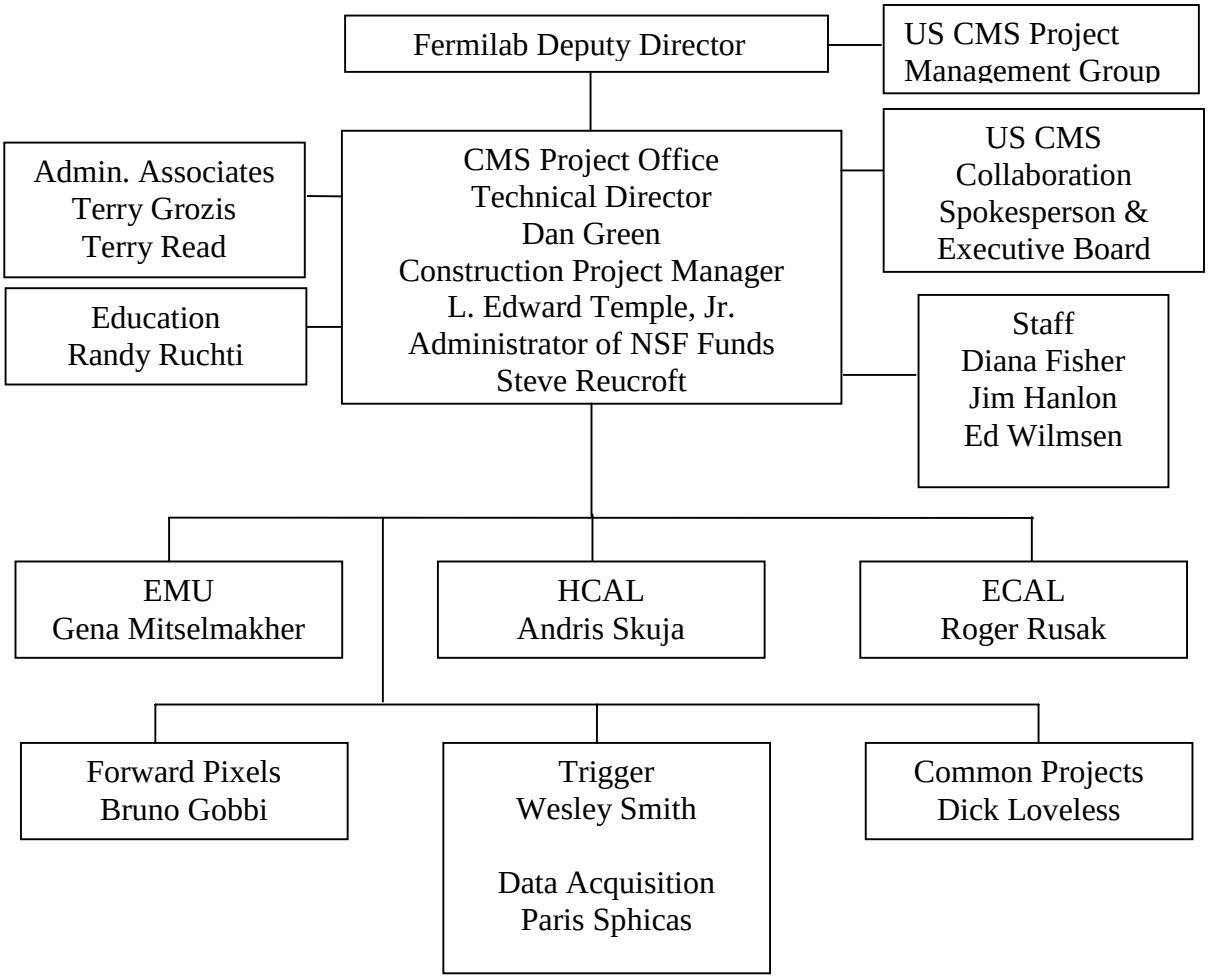


Fig. 5.1: US CMS Project and WBS Level 2 Managers

Section 6

Project Schedule and Milestones

6. Project Schedule and Milestones

6.1 Schedule Baseline

The CMS construction schedule provides the master schedule for construction. The schedule baseline sets forth the major activities, decision points, and activity interfaces essential for completion of the US CMS Project. The baseline schedule includes interpretation and optimization of activities related to the design, procurement, fabrication, assembly, testing, installation, and checkout of detector elements. A master schedule will be developed to include major activities and decision points. It is composed of major work breakdown structure level 3 elements including significant milestones. This schedule will be the top-level project schedule and is the basis for baseline development in all lower-level schedules.

Work package schedules at the lowest work breakdown structure level 7 will be assembled into an interconnected activity logic diagram by integrating construction activities within each respective work breakdown structure element. Schedule interfaces with other work breakdown structure elements will be made. This integrated schedule provides a total project critical path. Summarization of these lower-level activities allows status to be rolled up through the various WBS levels to provide intermediate-level and master-level working schedules. These working schedule dates are compared to the established baseline dates, and any variances are addressed in progress reports. Consistency of data from work packages through intermediate schedules to the master schedule will be traced through control and event milestones. All milestones contained in the project master schedule are reflected in the lower-level schedules.

The schedule management and monitoring system will be developed using Microsoft Project, a software tool available at Fermilab and one adopted by CMS. The schedule status is summarized at the various work breakdown structure levels to provide project schedule reporting at the master, intermediate, and detailed levels by work breakdown structure and across functional organizations. The master-schedule will also include a critical path, defined by the construction project manager by considering the critical paths of each of the level 2 efforts.

6.2 Baseline Milestones

A set of project milestones for the level 1 schedule has been defined by the US CMS Collaboration, in consultation with CMS. The level 1 schedule for US CMS and the corresponding CMS milestones appear in the CMS Memorandum of Understanding. The level 2 managers provide subsystem schedules, which are then linked to the level 1 milestones. This linked US CMS schedule is then resource loaded to provide a US CMS cost profile.

A list of controlled milestones that constitute the schedule baseline for change control purposes is given in Appendix 3.

Section 7

Cost and Labor Estimates

7. Cost and Labor Estimates

7.1 Cost Baseline

The cost baseline will be established when it is approved by the Joint Oversight Group. The project cost baseline is equal to the sum of the budgeted costs for each element of the Work Breakdown Structure described in Section 5. Changes in cost, technical requirements, schedules, and plans are to be treated as variances to the baseline.

Based on the DOE/NSF baseline review, the total project cost for the US CMS Project is $167,250K including $14,508K for escalation and $6,920K for R&D. This total should not be exceeded. The US CMS Project cost in FY 1997 dollars is $152,742K. Included in the cost are procurement, assembly, and installation of all technical components, engineering design, inspection, and project management required to assure successful completion of the project. Contingency funds equal to 43% of the base cost, excluding common projects, are also included.

7.2 Obligations and Cost Plans in FY 1997 Dollars

The original construction cost estimate was prepared in fixed-year (FY 1997) dollars. The construction cost in FY 1997 dollars is $145,756K.

7.3 Escalation

Escalation rates are based on an assumed annual escalation rate given by guidance from DOE.

7.4 Budget Authority and Funding Profile

The project baseline schedule, obligations, and cost plan will be based on the best estimate of the funding profile. The obligation plan will be derived from the baseline schedule and cost plans given in this project management plan. Similarly, application of the escalation rates given in Section 7.3 above will result in the cost plan.

7.5 Labor Requirements

Labor requirements have been estimated for each work package in the US CMS Project. These estimates include the required engineering, design, inspection, and acceptance and Fermilab-based project management, as well as manufacturing labor.

Section 8

Project Management System

8. US CMS Project Management System

8.1 Introduction

The CMS Project uses the work breakdown structure described in Chapter 5 as a framework for preparing a detailed cost estimate and a resource-loaded schedule. The work breakdown structure dictionary provides the initial input for the technical scope baseline given in Appendix 2. The time phasing of the resource-loaded schedule has been adjusted to fit within the anticipated funding profile. This then forms the basis for the cost baseline or budget shown in Appendix 4. This system is described in more detail in a US CMS project office procedure.

8.2 Change Control, Change Authorization and Contingency Management

The US CMS Fermilab construction project manager and technical director will control changes in requirements, cost, and schedule (in consultation and agreement, as appropriate, with the US CMS project management group). Any change that affects the interaction between detector subsystems or that significantly affect the performance, schedule, or the safety of the detector must also be referred to the CMS Management Board by the construction project manager and technical director.

DOE and NSF will make funds available for support of the US CMS Project on an annual basis. Each year the construction project manager and technical director review, negotiate, and approve the Statement of Work which will include a description of the work to be performed, the requested funds, and the manpower to be assigned to that year's activities. Also, through reviews, the projected cost of the work, and the currently projected contingency requirement at work breakdown structure level 3 over the life of the project will be known. Funds will then be released to the institutions that are part of the US CMS Collaboration. A management reserve will be held by the construction project manager and will be applied during the fiscal year on the basis of performance and need, following the principles of change control outlined below.

The Project Management Group, chaired by the Fermilab deputy director, will act as a high level Change Control Board for the US CMS Project. The Project Management Group will have as its purview assignment of contingency funds, changes of the scope of the project, and changes to the schedule exceeding thresholds shown in Appendix 6. Scope reductions may be required should projected costs of any level 2 subsystem greatly exceed the budgets to complete.

Formal change requests will be submitted and dispositioned (either approved or disapproved) for all changes exceeding thresholds stated in Appendix 6. The Project Office will maintain a record of all change requests. A *de minimus* level for cost changes is set at $1,000.

The principles of contingency management that the US CMS Project will follow are as follows:

- The cost estimate for each level 2 subsystem will include a contingency estimate based on an assessment of uncertainties and risks associated with the budgeted cost.
- Actual expenditure of contingency will be reflected in a revised estimate at completion, updated at least annually.

The Fermilab US CMS Project Management Group will consider and approve or disapprove all change requests that trigger the threshold set in Appendix 6. The US CMS Project Office will maintain a log of such approved (at any level) change requests. This log will be available for review by all project management.

- All cost changes to the baseline costs shall be traceable.
- The construction project manager must approve in advance all procurements requiring the use of contingency.

Section 9

Reporting and Review

9. Reporting and Review

Tracking and reporting hinges around a monthly status report comprising a technical progress report and a cost performance report. The latter is a monthly report, used by the US CMS Project Office and level 2 managers in the following format at various levels of the work breakdown structure. The report is used to monitor and assess status at a given time and provide information for current period, cumulative to date, and at completion. For example:

SAMPLE FORMAT OF THE US CMS COST PERFORMANCE REPORT

		MONTHLY					CUMULATIVE					AT COMPLETION		
DESC.	WBS	BCWS	BCWP	ACWP	SV	CV	BCWS	BCWP	ACWP	SV	CV	BAC	EAC	VAC
EMU	1.1	$6	$5	$5	($1)	$0	$60	$55	$50	($5)	$5	$241	$241	$0
HCAL	1.2	$8	$9	$7	$1	$2	$80	$90	$70	$10	$20	$276	$276	$0
TRIG	1.3.1	$3	$3	$3	$0	$0	$25	$25	$30	$0	($5)	$620	$620	$0
DAQ	1.3.2	$2	$3	$2	$1	$1	$20	$21	$19	$1	$2	$477	$477	$0
ECAL	1.4	$5	$6	$5	$1	$1	$50	$55	$45	$5	$10	$715	$715	$0
FPIX	1.5	$9	$8	$7	($1)	$1	$15	$16	$10	$1	$6	$167	$167	$0
CP	1.6	$5	$5	$6	$0	($1)	$50	$50	$55	$0	($5)	$230	$230	$0
PO	1.7	$6	$6	$5	$0	$1	$58	$58	$50	$0	$8	$574	$574	$0
TOTAL	CMS	$44	$45	$40	$1	$5	$358	$370	$329	$12	$41	$3,300	$3,300	$0

The monthly reports to the agency project manager will be at level 2. Internal reports can be prepared at any level desired (e.g. level 3 and/or 4 for primary hardware or extremely high-risk items). The US CMS project will collect costs at the lowest level reasonable. Summary reporting at work breakdown structure level 2 or even level 3 is adequate because any time a variance threshold is penetrated, the CMS Project Office must describe what is happening. This will be required under variance analysis reporting for cumulative to date and at completion periods. The reporting is passed to the construction project manager and the Project Office, which is responsible for tracking all US CMS funds. Each institution will provide monthly financial information to the construction project manager in a specified format, which provides cost and schedule variance analysis information. Each level 2 manager will provide monthly reports on technical progress to the construction project manager and the technical director.

Tracking and reporting and the record of performance will form the basis for continuing annual authorization of funds. Authorization to a particular institution is performed by the construction project manager. This is accomplished with the scientific advice of the technical director. This is completed within the framework of the US CMS Memorandum of Understanding and annual Statement of Work.

The US CMS Project reports cost, labor, schedule, and performance data to the Fermilab deputy director and the agency project manager. The objective of the reporting and review activity is to provide for the collection and integration of essential technical, cost, schedule, and performance progress data into the reports and reviews needed for managing and monitoring the US CMS Project. The following paragraphs describe the status and technical reports that will be provided. They also address regular meetings and reviews.

9.1 Meeting and Reviews

9.1.1 Internal US CMS Meetings

Weekly meetings will be held between the construction project manager and technical director and the level 2 managers to discuss progress, problems, and focus resources as appropriate.

Monthly meetings will be held between the construction project manager and technical director and each level 2 manager using the monthly report as a point of departure for reviewing and assessing progress and problems and discussing and agreeing on proper courses of action.

The US CMS construction project manager, technical director and level 2 managers will meet regularly with the US CMS Executive Committee to assess the current status of the project, management issues, and proposed major changes. Communication with the US CMS Collaboration at large is done at the biennial US CMS full-collaboration meetings.

9.1.2 Meetings with Fermilab as Host Laboratory

Regular meetings of the Project Management Group will be held. The US CMS construction project manager and the level 2 managers will review current status of project work, discuss outstanding issues, and update previously identified action items. The agency project manager will be an observer at Project Management Group meetings.

9.1.3 Meetings with DOE and NSF

Weekly Meetings

A weekly meeting will be held between the construction project manager and the agency project manager.

DOE/NSF Sponsored Reviews

DOE and NSF will conduct comprehensive reviews of the technical, management, cost, and schedule of the project. It is expected that these reviews will be conducted at least annually and that status reviews will be conducted every six months. In preparation for the annual reviews, the construction project manager will direct an annual cost-to-complete analysis, based on experience to date.

Appendix 1: Memorandum of Understanding

Memoranda of Understanding will exist both within the CMS collaboration as a whole, and for the US CMS collaboration.

A Memorandum of Understanding is negotiated between CERN as the host laboratory, the collaborating CMS institutions (represented by the CMS Collaboration Board) and their funding agencies (DOE and NSF in the US). A draft of an Interim Memorandum of Understanding covering the initial phase of the CMS experiment has been signed for the 1996 and 1997 period of R&D.

Within the US CMS Project, a US Memorandum of Understanding will be executed. Draft versions of this Memorandum of Understanding and of the annual Statement of Work have been written, and appear here as Appendixes A and B. The signatories of this Memorandum of Understanding are threefold: Fermilab as host laboratory, the US CMS collaborating institution, and the US CMS construction project manager. By means of the Memorandum of Understanding agreement, the level 2 managers and the US CMS project manager will identify the work to be done at each member institution of US CMS, together with the necessary resources. It will also establish reporting to be done by each institution of both financial and schedule milestones.

DRAFT

Memorandum of Understanding
Between

<Institution>

and

US CMS Collaboration
Project Management
At Fermilab

<date signed>

Introduction

This Memorandum of Understanding describes the collaboration by members of <Institution> in the Compact Muon Solenoid (CMS) Project in the United States. The purpose of this collaboration is the design, fabrication, operation, and scientific exploitation of the CMS Detector. The detector is described in the CMS Technical Proposal, (December 15, 1994), the Technical Design Reports, and subsequent technical documents elaborating that design. The contribution of the US CMS Collaboration to the CMS Detector Project is defined by the scope of work set out in the US CMS work breakdown structure and accepted as the baseline set of

deliverables by DOE and NSF. This scope of work forms the basis of the Memorandum of Understanding between CERN and DOE/NSF.

The US CMS project management infrastructure (US CMS Project Office) resides at Fermilab, and the responsibility for US CMS project management resides in the US CMS technical director and construction project manager, who report to the US CMS Fermilab Project Management Group and the Fermilab deputy director. The US CMS technical director/ construction project manager have appointed level 2 managers who are responsible to them for subsystems of the US CMS project.

This Memorandum of Understanding describes the long-term contributions of <Institution> to the design, construction, and operation of the CMS Detector. It is understood that these contributions of <Institution> may later be modified or that additional responsibilities may be added. The US CMS project finishes at the end of FY2004.

An annual Statement of Work will detail the contributions of <Institution> as the detector construction proceeds and will contain the specific activities, deliverables and funding required. The normal period of performance will be the US fiscal year (October 1-September 30). A separate Statement of Work will be written for each level 2 subsystem, while the Memorandum of Understanding will be a single document for each US CMS institution. In FY98 Statements of Work were written with all institutions then participating in the project.

This Memorandum of Understanding is made between <Institution>, the US CMS technical director/construction project manager and Fermilab as part of its role in management oversight. It does not constitute a legal contractual obligation on the part of any of the parties. It reflects an arrangement that is currently satisfactory to the parties involved. The parties agree to negotiate amendments to this memorandum as required to meet the evolving requirements of the CMS detector construction program.

Personnel

2.1 List of Scientific Personnel

Participating scientists committed to CMS over the full project period are listed below. No support for these individuals comes from project funds.

Name	CMS Fraction*	Other Research Commitments/Comments

*Time devoted to CMS over and above the indicated CMS research fraction is considered to be <Institution> service effort in support of CMS.

2.2 Collaboration Board Representative

<Name> is the present representative of <Institution> to the US CMS Collaboration Board.

2.3 List of Technical Personnel

Participating technical personnel with the anticipated fraction of their time (time fractions are estimates and are not cost shares) committed to CMS during this period of performance and their source(s) of support are indicated below. The possible sources are DUS = DOE. US CMS Project: NUS = NSF. US CMS Project: DBG = DOE base grant; NBG = NSF base grant. UID = university infrastructure. DOE-supported group; and UIN = university infrastructure. NSF-supported group as shown in the WBS.

Engineers

Name	CMS Fraction*	Cost on CMS Project	Source of Support

Designers

Name	CMS Fraction*	Cost on CMS Project	Source of Support

Technical Specialists

Name	CMS Fraction*	Cost on CMS Project	Source of Support

Programmers

Name	CMS Fraction*	Cost on CMS Project	Source of Support

Others

Name	CMS Fraction*	Cost on CMS Project	Source of Support

2.4 Other Key Personnel

The Environment, Safety and Health officer for <Institution> currently responsible for compliance with applicable ES&H policies associated with CMS participation by this institution is <ES&H Name> of <Institution>. The quality assurance officer for the US CMS group at <Institution> currently responsible.

<Institution> responsible for quality assurance compliance of tasks performed by this institution is currently <name> of <Institution>. [Persons identified in this section are typically ES&H and quality assurance professionals who provide assistance to line personnel responsible for CMS activities.]

3 Design, Fabrication and Installation Responsibilities

3.1 Design and Fabrication Responsibilities – Construction Period

3.1.1 Work Breakdown Structure Items at Level 2. Estimated Cost and Deliverables

The US CMS Work Breakdown Structure contains a detailed cost estimate of the items needed to complete the US CMS project. By this Memorandum of Understanding <Institution> agrees to make a best effort to provide the following items at a cost not to exceed the work breakdown structure base cost estimate. Procedures to be followed in the event of a necessary variation of cost from the base cost are described in Section 3.3 below. The table below lists the work breakdown structure summary items at level 2. Appendix A gives the full work breakdown structure of the items to level 7.

WBS (L2)	Task – Deliverable	WBS Base Cost	Cost at this Inst.	FNAL MPO	DOE Suppl.	NSF
Total	Requested Project funds ($k)	---				

3.1.2 Transportation

Unless specifically indicated otherwise here, items produced by <Institution> for use in the CMS detector or subsystems shall be transported by the providing institution to the agreed upon point of delivery. <Institution> shall be responsible for safe transport of all items to these delivery points. The method of transport and packaging are to be authorized by the US CMS project office in consultation with the appropriate level 2 lead engineer.

3.1.3 Installation and Commissioning

<Institution> will participate in the installation and commissioning of their contributed items at CERN as listed. The <Institution> will also participate in the maintenance and operation of these items.

<Item 1>

<Item 2> . . .

3.2 Coordination and Reporting

The US CMS level 2 manager for the <subsystem> subsystem is <name 1>. This institution contact person for <subsystem> activities at <Institution> is <name 2>. The task managers for <subsystem> activities carried out at <Institution> are as follows

Task	Task Manager

The progress of the design, fabrication, and testing of these components will be reported by the above-named task managers on a monthly basis, by work breakdown structure element to level 3 in detail, to the US CMS level 2 manager, who in turn will report subsystem progress to the US CMS technical director/construction project manager. The technical director/ construction project manager will, in turn, report to the Fermilab project management group.

Technical reporting to CMS project management will be performed by the US CMS Subsystem Coordinator. Financial reporting to CMS will be made by the US CMS construction project manager.

The authorized financial officer at <Institution> is <name>. The US CMS technical director/ construction project manager delegate expenditure authority regarding the designated work breakdown structure items in the Statement of Work to the authorized financial officer subject to the following requirements. The base cost of the work breakdown structure items is given in Section 3.1.1 without contingency. The officer agrees that these cost ceilings cannot be exceeded without the authorization of the technical director/ construction project manager and the relevant level 2 manager. In addition, the officer agrees that item purchases exceeding the delegated limit (currently 10 k$) must be authorized by the US CMS level 2 manager.

Major procurements (currently 100 k$) must in addition have the written authorization of the US CMS technical director/ construction project manager. Items purchased as CMS Common Project items (work breakdown structure category 6) must be explicitly authorized by the US CMS technical director/construction project manager and approved by the CMS Finance Board Chair, regardless of the cost. Items purchased for Project Office (work breakdown structure category 7) must be authorized by the technical director/ construction project manager.

3.3 Reporting to US CMS Project Management

<Institution> will report all CMS related expenditures and labor charges together with associated technical progress in each item of work by Work Breakdown Structure category (Level 7) on a monthly basis through the appropriate US level 2 manager(s) to the US CMS technical director/construction project manager. Cost reporting will apply to US CMS Project funds related to detector fabrication. Other, non-DOE and non-NSF costs will be reported in a manner that is agreed to by the level 2 manager(s), the US technical director/construction project manager and <Institution>. Any request for variance from the base cost must be immediately reported to the appropriate level 2 manager.

Technical progress will be reported by WBS element level 4 to the level 2 manager and the technical director/construction project manager on a monthly basis and will cover all items covered in this Statement of Work regardless of the specific nature of the funding support.

The <Institution> agrees to furnish complete documentation of the quality control and performance checks that are carried out for US CMS. Further, the institution agrees to furnish full documentation of all equipment and services that it provides for the US CMS project. This will include engineering drawings of equipment, full schematics of electronics, and documentation of all software. Where relevant, an acceptable level of spares (~10 percent) will be provided and maintained by the institution.

Each US CMS group at <Institution> agrees, with this document, to set up and maintain a ledger, of a form specified by the US CMS Project Management. This ledger will contain information on cost items at level 7 of the US CMS work breakdown structure. Each Institution agrees to provide and maintain this ledger so as to provide timely information to the level 2 manager and the US CMS technical director/construction project manager.

3.4 Collaboration with Other Groups and Institutions

Design, construction and installation related to the <subsystem> subsystem will be carried out in close communication and collaboration with other groups working on this and related subsystems.

WBS / Task (L4)	Collab. Group	Responsibility with <Institution>

4. Contribution of Effort, Services and Equipment

4.1 Effort

Subject to funding by DOE or NSF, <Institution> will provide support for the scientific and technical personnel as indicated in Section 2. This contribution refers only to support provided outside the US CMS Project.

4.2 Services

The services of the <Institution> Purchasing, Expediting, and Receiving Departments and the Administrative Staff will be available to the CMS project to the degree required to carry out the fabrication responsibilities of <Institution>. By this Memorandum of Understanding, <Institution> agrees to provide the services of the responsible financial officer.

4.3 Facilities and Equipment

The following <Institution> facilities and equipment will be made available to the CMS project to the degree necessary to carry out the design and fabrication responsibilities of the group:

Facilities and Equipment:

4.4 Operating Costs

<Institution>, subject to the availability of funds from DOE or NSF, will support the normal research operating expenses (such as physicists' salaries, travel expenses, miscellaneous supplies, administrative support, etc.) of the <Institution> group working on the CMS project. These normal operating expenses are not considered as part of the CMS detector cost estimate nor will they be borne by the US CMS project.

5. Fermilab (as host institution) Effort, Services, and Facilities

Tracking of Fermilab CMS support, whether provided by Fermilab or paid by the US CMS Project, will be done using appropriate effort reporting codes. The costs incurred will be reported to the Fermilab director.

Subject to agreement, to be negotiated annually with the Fermilab director, <Institution> expects the following Fermilab resources to be available in support of <Institution's> design, fabrication, and installation responsibilities:

5.1 Administrative and Technical Personnel

Participating Fermilab staff members foreseen to be available to the project are:

Administrative Staff

Name	CMS Fraction	Source of Support

Engineers

Name	CMS Fraction	Source of Support

Designers

Name	CMS Fraction	Source of Support

Technical Specialists

Name	CMS Fraction	Source of Support

Programmers

Name	CMS Fraction	Source of Support

Others

Name	CMS Fraction	Source of Support

Administrative and technical staff salary support may be paid by the US CMS Project, or may be provided by Fermilab as project host. The salary support of Fermilab staff contributing to <Institution's> responsibilities must be negotiated annually with the Fermilab director as part of the Statement of Work. Support provided by Fermilab will be tracked and reported to the Fermilab director and the project management group.

5.2 Services

The services of the Fermilab Purchasing, Expediting, and Receiving Departments are expected to be available to <Institution> for the procurement of the following items:

<Item 1>

<Item 2> . . .

5.3 Facilities and Equipment

<Institution> expects that the following Fermilab facilities, equipment, and laboratory space will be available during the course of the project:

Facilities, equipment, and laboratory space:

Costs and Funding

6.1 Expected Sources of Funding

The cost of the detector elements covered under the US CMS WBS are taken in detail from the current US CMS Cost Estimate (<Date>). DOE (NSF) Funds indicate the project funds expected to be provided over the lifetime of the project. <Institution> agrees not to exceed the costs shown above, estimated cost less contingency, subject to the procedures given in Section 3.3.

6.2 Management Reserve

Each year, a Statement of Work will be written with each US CMS Institution for each level 2 subsystem that is relevant. The allocation of funds for the fiscal year will be in two parts. The first will cover work for the first six months. The remaining funds needed to complete the tasks described in the Statement of Work will be provided subject to availability of funding and performance during the first half year. Management control requires the review and concurrence of the level 2 manager and the technical director/construction project manager, as needed, for

major expenditures, as defined above. The release of funds above the given thresholds by the responsible financial officer as named above will be contingent upon this concurrence.

Method of Funding Transfers

The expenditures by <Institution> are to be covered by funds provided by DOE or NSF, upon the allocation decision of the US CMS technical director/construction project manager with the concurrence of the US CMS Fermilab project management group.

Funds to cover work or expenditures described in this document may be provided directly to <Institution> by DOE or NSF, or by subcontract from the US CMS Project Office at Fermilab. The choice of funding method shall be at the option of the technical director/construction project manager.

All equipment items bought or fabricated using DOE or NSF funds will be properly marked as the property of DOE or NSF. Any other equipment furnished by <Institution>, as part of the detector will remain <Institution> property. In either case, the equipment will remain part of the CMS detector until it is dismantled or the detector element in question is replaced.

General Considerations

8.1 Safety and Engineering Practices

The experimenters from <Institution> agree to familiarize themselves with DOE and NSF safety policies and to adhere to them. All detector components must be designed, fabricated, installed and operated in conformity with DOE, NSF, and CERN safety policies and practices as well as DOE, NSF, and CERN engineering standards. All engineering, design, quality assurance, safety, and other activities shall be in compliance with International Organization for Standardization standards. All major components will undergo appropriate design, safety, and engineering reviews.

8.2 Operations

<Institution> agrees to maintain, to the best of their ability, equipment provided for the CMS detector as long as <Institution> is a member of the CMS collaboration.

Schedules and Milestones

<Institution> will make every effort to carry out their institutional responsibilities consistent with the schedule for the fabrication of the CMS detector. These schedules may have to be changed as the project progresses. Changes that affect <Institution> will be noted in the annual Statement of Work. The program milestones over the life of the project relevant to <Institution> are listed here:

Program Milestones	Baseline Milestone Date	Current Milestone Date

Makers and Concurrence

The following persons concur in the terms of this Memorandum of Understanding. These terms will be updated as appropriate in Amendments to this Memorandum.

Makers of this Memorandum:

Dan Green US CMS Technical Director	date	Administrative Officer <title> <Institution>	date
Ed Temple US CMS Construction Project Manager	date	<Name> Grants/Contracts Officer <Institution>	date
<Name> US L2 Manager <Subsystem> Subsystem	date	Principal Investigator <Name> <Institution>	date
<Name> US L2 Manager <Subsystem> Subsystem	date	Principal Investigator <Name> <Institution>	date
<Name> US L2 Manager <Subsystem> Subsystem	date	Principal Investigator <Name> <Institution>	date
<Name> US L2 Manager <Subsystem> Subsystem	date	Principal Investigator <Name> <Institution>	date

Concurrence:

Ken Stanfield Deputy Director Fermilab	date	<Name>	date

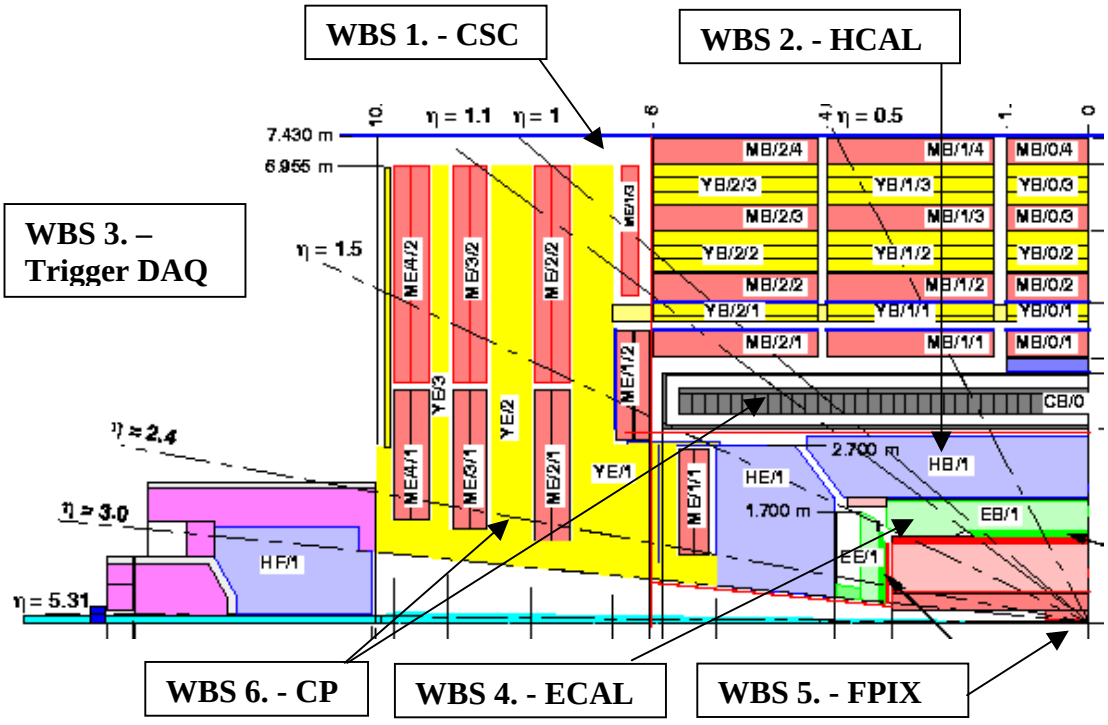
Copy sent to:

Alain Herve CMS Technical Coordinator Fermilab	date

Appendix 2: US CMS Technical Baseline Document

The US CMS Collaboration has agreed to take leadership responsibility in the CMS experiment for the endcap muon system, all the hadron calorimetry, and associated aspects of the trigger and data acquisition system. The Collaboration also plans to contribute to important areas of the electromagnetic calorimetry, tracking, and common projects. The general layout of the CMS Detector is shown in Figure 1.

A summary description of the US CMS baseline scope is provided below. The details at the lowest work breakdown structure level are available in the US CMS work breakdown structure dictionary dated May 19, 1998. Level 2 WBS numbers associated with the various subdetector or subsystems efforts are identified in Figure 1.



1. Endcap Muon – cathode strip chambers
2. Hadron Calorimeter – full HB, HOB, He, and HF transducers and readout – HE scint, HF QP fibers
3. Endcap Muon and Calorimeter Trigger. DAQ filter
4. Electromagnetic Calorimeter – barrel transducers, front end electronics, and laser monitor
5. Forward Pixels
6. Common Projects – endcap yoke and barrel cryostat
7. Project Office

Figure 1

WBS 1.1 – Endcap Muon System (EMU):

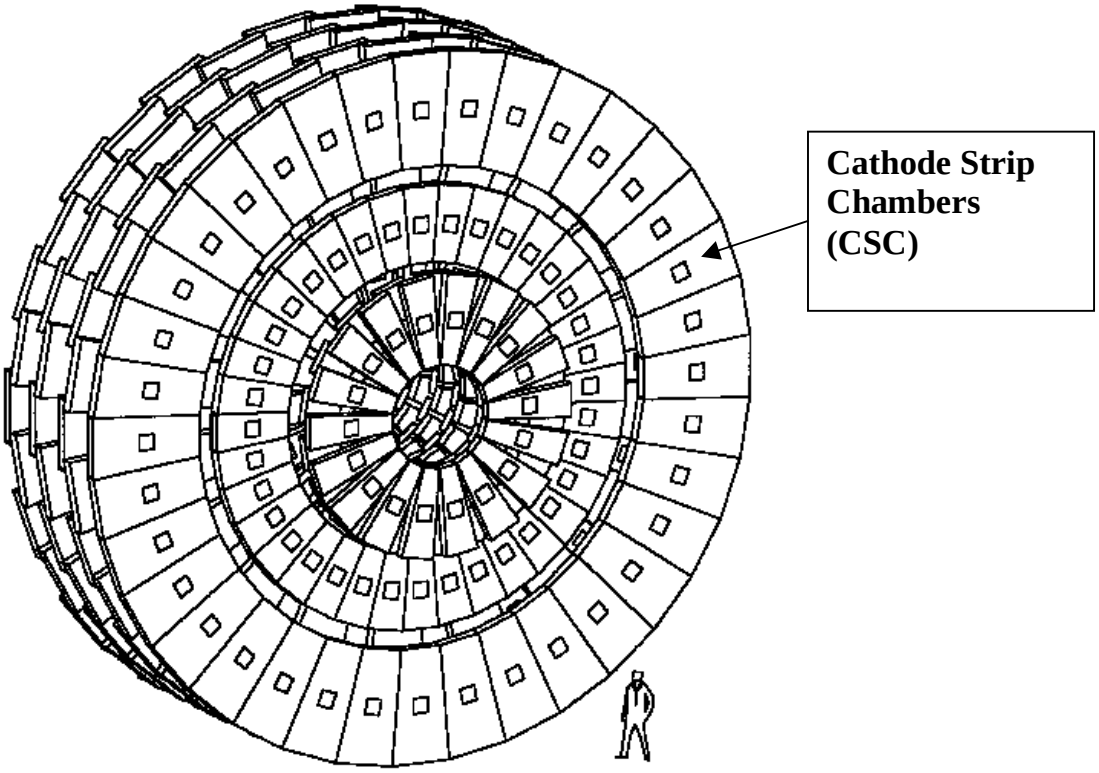


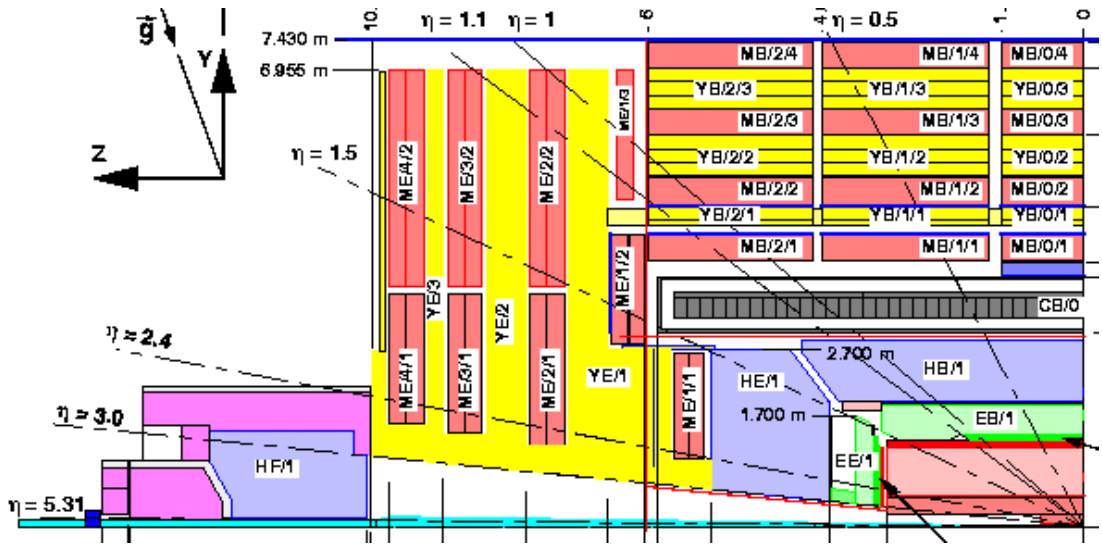
Figure 2

The CMS Endcap Muon System consists of three muon stations (four stations are shown in Figure 2; the fourth station was eliminated as part of the US CMS rescoping exercise) interleaved with three iron disks. The angular region covered is $0.9 < \eta < 2.4$. Here η is the pseudorapidity, that is $-\ln[\tan(\vartheta/2)]$, where ϑ is the angle to the beam axis. Muon stations are six-plane trapezoidal cathode strip chambers. A precise coordinate measurement in cathode strip chambers comes from interpolating charges induced by cathode strips.

The total number of chambers in the endcap system for the US CMS baseline is 360 (372), where the number in parentheses includes spares. The largest cathode strip chambers are 3.4 x 1.5 m^2 in size. Each chamber consists of six trapezoidal planes. Strips run radially to provide a precise measurement of the ϕ coordinate, while wires run azimuthally and define the radial coordinate of the track. The overall area covered by the chambers is more than 950 m^2 and the total number of wires exceeds 1.7 million.

The US will manufacture, instrument, and install 148 large chambers, and will make parts kits for the assembly of 148 smaller chambers by China, and 76 smaller chambers by Russia. The US is responsible for all parts, critical tooling, the on-chamber electronics, and the level 1 trigger.

There are 5 types of chambers shown schematically in Figure 3.



ME23/2 – largest chambers, 10-degree in ϕ, outer ring of stations 2, 3
ME2/1 - inner ring of station 2, 20-degrees in ϕ
ME3/1 - inner ring of station 3, 20-degrees in ϕ
ME1/2 - intermediate ring of station 1, 10-degrees in ϕ (high resolution CSC)
ME1/3 - outer ring of station 1, 10-degrees in ϕ

Figure 3

The ME23/2 are entirely the responsibility of the US.

For ME234/1 the US provides parts and critical assembly tooling. PNPI (Russia) is responsible for assembly, testing, shipping, and commissioning. For ME1/23 the US provides parts and critical assembly tooling. IHEP (China) is responsible for assembly, testing, shipping, and commissioning.

WBS 1.2 – Hadron Calorimeter (HCAL):

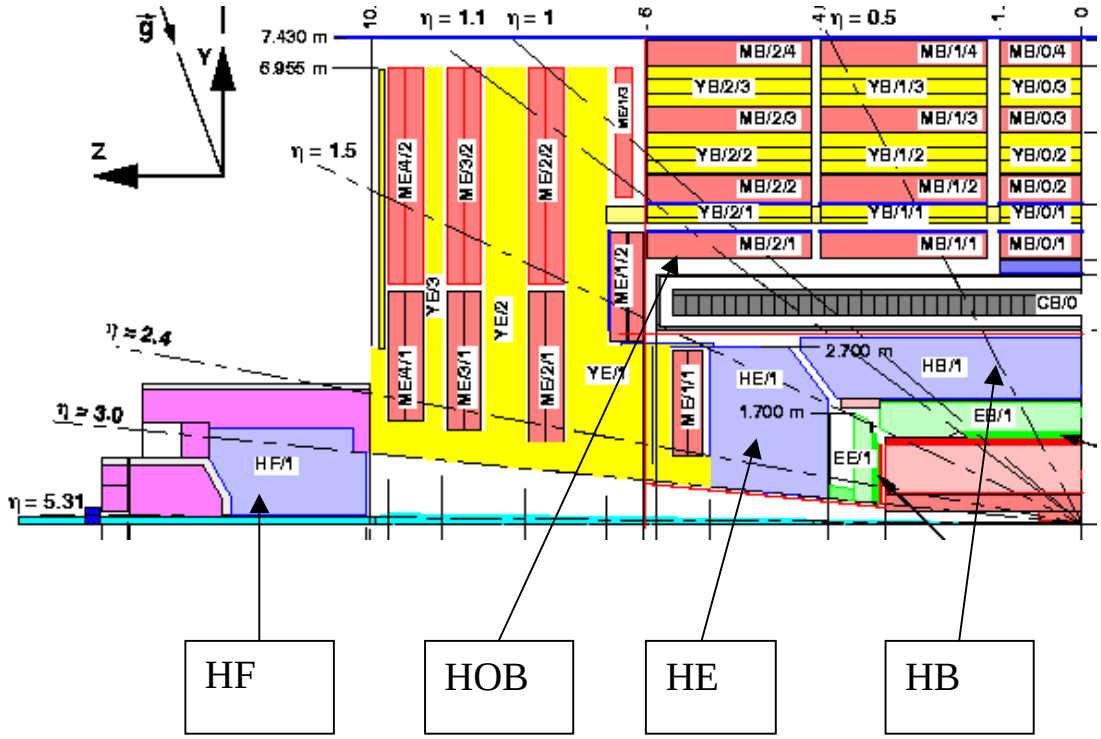


Figure 4

The hadron calorimeter, shown schematically in Figure 4, in CMS is organized geographically. There are five mechanically distinct structures: the barrel (HB, 0. < η < 1.3), 2 endcaps (HE, 1.3 <η < 3), and the 2 forward (HF, 3 < η < 5) calorimeters. The US CMS hadron calorimeter group responsibilities are to produce the barrel absorber and the barrel scintillator tile/wave length shifter optics. In HF the US will supply none of the absorber, but a fraction of the quartz fiber sampling medium. In addition, the US will produce the barrel, outer barrel, endcap, and forward transducers and front end electronics.

The hadron calorimeter is organized into towers of size $\Delta\eta\Delta\phi$ = 0.087 x 0.087 for the barrel and endcap and $\Delta\eta\Delta\phi$ = 0.174 x 0.174 for the forward calorimeter. There are 3 longitudinal depth segments H1, H2, and HO in HB. In HE there are two depth segments, while HF has three; HFE, HFH, and HFT.

The work breakdown structure 1.2 items include all the effort to design, produce, assemble, install, and commission the hadron calorimeter for the CMS detector. The HB calorimeter is constructed of 36 wedges, each weighing ~ 26 tonnes. The absorber is copper for HB and HE. The minimum HCAL depth is 5.8 interaction lengths inside the CMS coil. The HE is built as a single unit, but the optical system is packaged as 18 distinct 20-degree “pie” wedges, thus matching the HB segmentation.

There are distinct calorimeter towers in $\Delta\eta\Delta\phi$ and in longitudinal depth. These are supplied with electronics channels, which amplify and digitize the signals produced by the HPD (HB, HOB, HE), and read out the PMT (HF). The channel count (excluding spares) is 5184 in HB, 2160 in HOB, 3774 in HE, and 1728 (1920) in HF. The resulting digital signals are stored in a pipeline and sent to the trigger/DAQ system by means of multiplexed fiber optic communication systems. The received data is sent to the trigger and DAQ systems separately. The system is calibrated using LEDs, radioactive sources, and lasers.

WBS 1.3 – Trigger/Data Acquisition (TRIDAS):

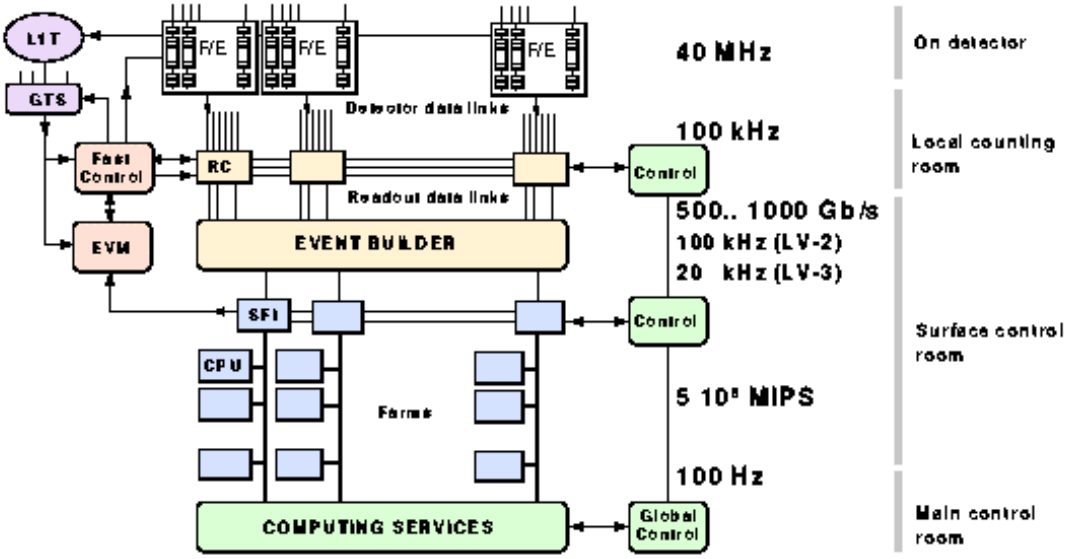


Figure 5

US CMS is responsible for elements of the first level muon trigger and the level 1 calorimeter trigger. In addition, US CMS takes responsibility for the data acquisition filter units (FU), and the event manager (the layout of the data acquisition system is shown in Figure 5).

WBS element 1.3.1.1 includes all the effort to develop, produce, assemble, install, and commission the Regional Muon Trigger. The system is designed with 3 muon stations; however, the design allows easy expansion to a 4-station system. The US will provide Port Cards (55), Sector Receiver Cards (56), and Sector Processor cards (30) for the level 1 CMS Muon Trigger.

Work breakdown structure element 1.3.1.2 includes all the effort to develop, produce, assemble, install, and commission the Regional Calorimeter Trigger. This system processes the electromagnetic and hadronic trigger tower sums from the calorimeter front end electronics and delivers regional information on electrons, photons, jets, and partial energy sums to the global calorimeter level 1 trigger system. The system begins after the data from the front end electronics is received on optical fibers and translated to signals on copper and ends with cables that transmit the results to the calorimeter global level 1 trigger system. The trigger is based on a

54 x 72 (η x ϕ) array of ECAL and HCAL trigger towers. The towers supply 8 bits of energy information. The US provides 22 VME crates with custom backplanes.

Work breakdown structure element 1.3.2 includes all the effort to develop, produce, and assemble the parts of the CMS Data Acquisition system for which the US CMS groups are responsible. The US has undertaken the responsibility to provide the full Filter Unit system and the complete Event Manager system. In the R&D phase, US groups will also participate in the design and testing of prototyping modules that can be used both on the Readout Units and the 432 Filter Units. The complete DAQ system will perform at 75 kHz, and the system is scalable.

WBS 1.4 – Electromagnetic Calorimeter (ECAL):

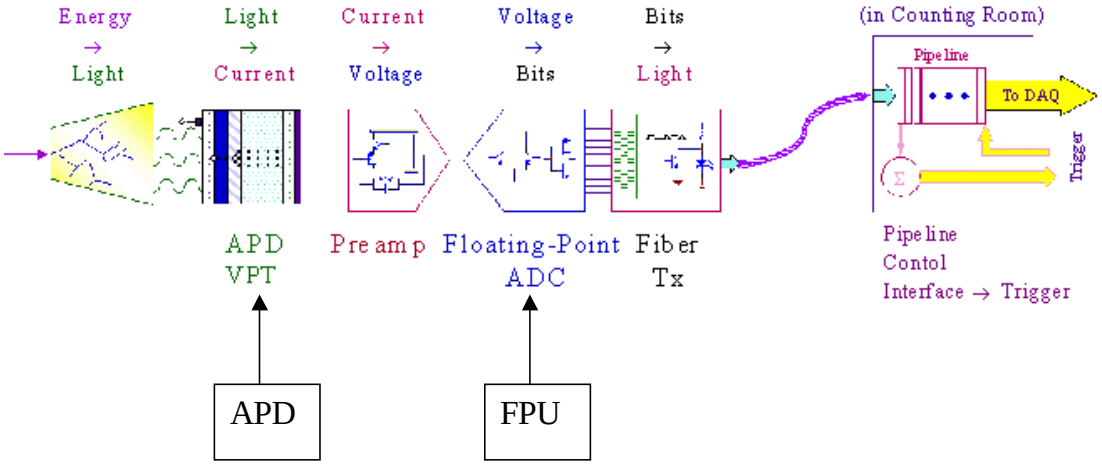


Figure 6

US CMS is responsible for elements (identified in Figure 6) of the electromagnetic calorimeter. This device utilizes $PbWO_4$ crystals to detect electromagnetic showers. The US is responsible for partial procurement, 36000, of the light transducer Avalanche Photodiode (APD), the floating point unit (FPU), 60200, which converts a voltage to a digital number, the bit serializer which converts that number into a serial bit stream for transmission off the detector, and elements of the laser monitor/calibration system.

There are 61,200 crystals in the barrel ECAL, or EB. Each has a pair of APDs with 25 mm^2 sensitive area. The US is responsible for ~50% of the APD prototypes and ~30% of the procurement of the production APDs.

The US is responsible for the design and procurement of all the EB front-end multi-ranging floating point units (FPU), and CHFET bit-serializers.

The US is responsible for elements of the laser monitor system. These include the laser, cooling, collimators, shutters, mirrors, and other optical mounts.

WBS 1.5 – Forward Pixel Tracking (FPIX):

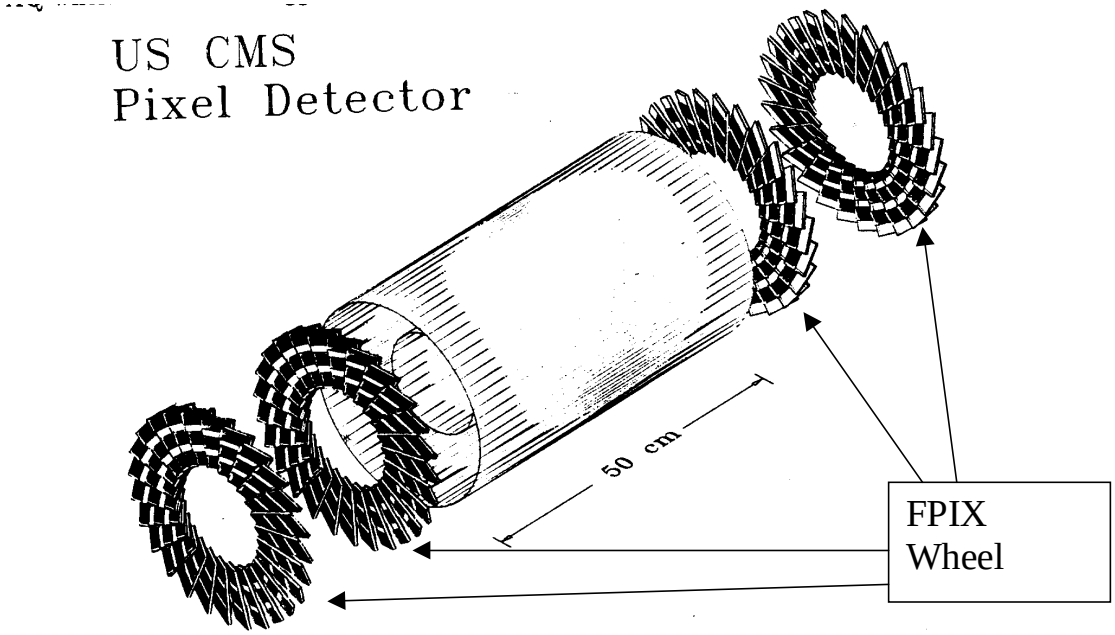


Figure 7

US CMS is responsible for the delivery of the forward silicon pixel (FPIX) detector system. This system consists of 4 assemblies, or wheels, (shown in Figure 7) of silicon pixels. These wheels are made from subassemblies, which are arranged as "turbine blades". This unique arrangement allows for Lorentz force charge sharing among pixels, thus enabling the devices to have good impact point resolution in 2 dimensions.

The FPIX system covers the angular range $1.4 < \eta < 2.6$. The US will design, assemble, deliver, install, and commission the entire system. This system consists of 4 disks containing 96 "blades". Each blade has 7 silicon sensor arrays comprising 45 readout chips. There are 4320 total readout chips and 672 Si sensors. The total system has ~12 million pixels, each 150 μm x 150 μm. The system consists of sensors, readout, mechanical support, and ancillary services.

WBS 1.6 – Common Projects:

Common Projects in CMS are the magnet and the common software and computing. The US pays a representative share of the Common Projects as defined to be a fixed fraction of the contribution of the US to CMS. The US contribution will be defined to be the M&S items of the baseline scope of the US CMS project. The fraction is currently assessed to be 31.5 percent. This currently agreed upon US contribution to Common Projects is $23M.

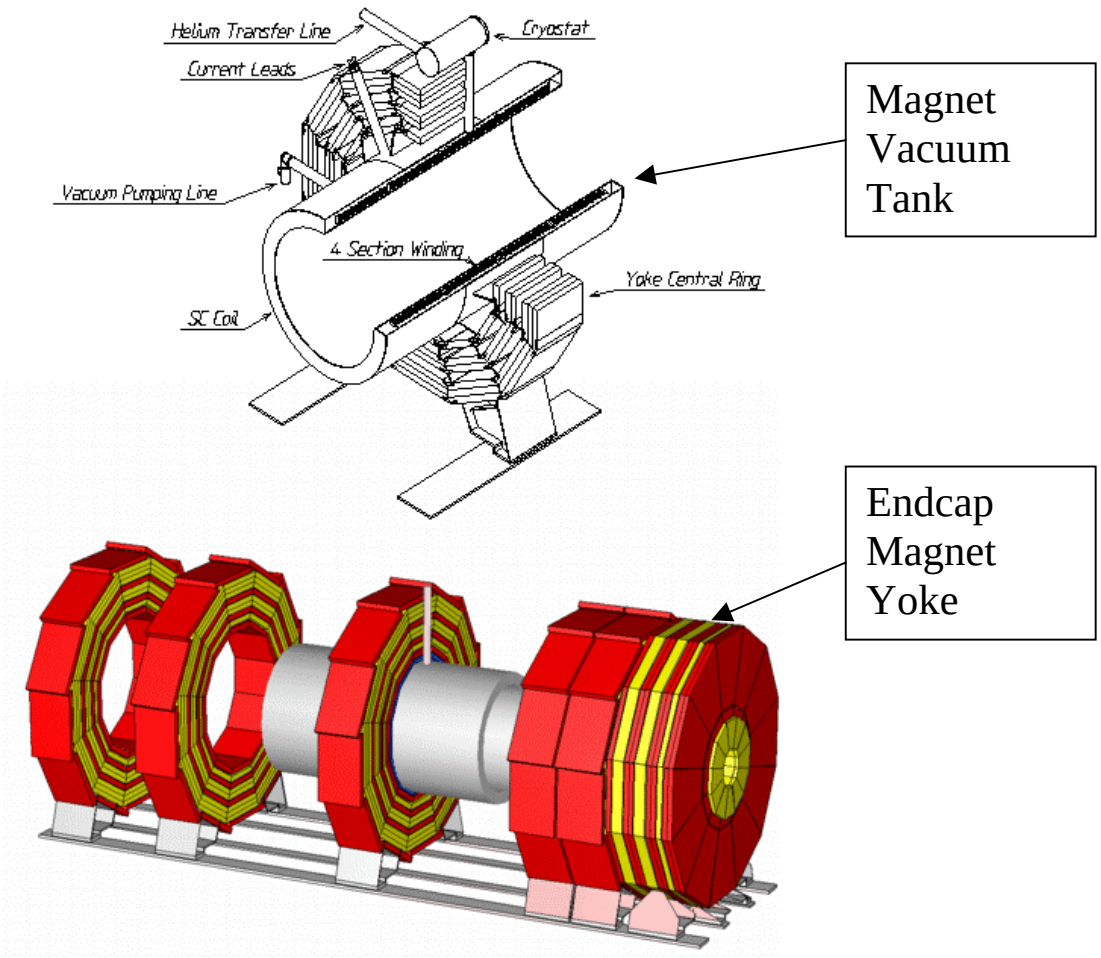


Figure 8

The US CMS contribution is made by material acquisitions rather than by cash payments. The two major efforts in US CMS are related to the US CMS interests in the hadron calorimeter and the forward muon system. This may evolve, as the cost experience with CMS Common Projects becomes clearer (i.e., we may be able to provide more or less than currently planned in the way of material acquisitions based on real cost experience.)

The US takes full responsibility for the design and procurement of the endcap steel yoke (shown as the yellow toroids in Figure 8 bottom). The US also takes partial responsibility for the barrel yoke and the coil vacuum tank (shown in Figure 8 Top). These two projects have already been bid and the contract for the endcap will be awarded within a few months. The contract for the barrel is already in place.

WBS 1.7 – Project Office:

This work breakdown structure element includes all the effort needed to exercise Project Management in CMS. The tasks include:

Baseline Development

The first phase of the US CMS Project is to construct a baseline cost estimate, have it reviewed, and accepted by the DOE and NSF as an acceptable estimate of the set of deliverables which can be supplied with high confidence for the total funding available to the project.

Tracking

A major function of the US CMS project office is tracking the progress of the project. That function includes the overall level 1 schedule, the level 2 linked schedules, and the derived annual Statement of Work. The actual costs are to be reported at the lowest work breakdown structure level by means of invoices to the Fermilab general ledger.

Reporting

The US CMS project office will report to the Fermilab Project Management Group, the DOE/NSF Project Manager, and the Joint Oversight Group in a manner specified by those entities.

Northeastern University Administration

The NSF funds will be sent from NSF to Northeastern University. They will be divided then as per instruction of the technical director/construction project manager and sent to the NSF supported groups of US CMS. In order to perform these functions, Northeastern University requires the services of an Administrative Assistant.

Support for Education/Outreach

The education liaison function includes the development of educational proposals of US CMS. In support of these and other educational activities, the US CMS project office supplies funds for programmatic travel and for M&S supplies.

Appendix 3: US CMS Schedule Baseline

JOG*	Date		APM / DD**	Date
1 DOE/NSF CERN Agreement	Dec-97	CP	1 Move 2nd Year Funding for CP Package A	Oct-98
2 Approve Baseline	Jul-98	EMU	2 Muon CSC*** Factory Start	Jan-99
3 Approve Project Management Plan	Sep-98	HCAL	3 HCAL Optics Factory Start	Jan-99
4 US CMS Project Complete	Oct-05	HCAL	4 1st 18 Wedges Optics @ CERN	Jun-00
		HCAL	5 1st 18 Wedges HCAL Brass @ CERN	Nov-00
		FPIX	6 FPIX Cooling Distribution Design Complete	Jan-01
		CP	7 4th Year CP Package A Payment Complete	Jun-01
		EMU	8 1st 17 EMU CSC Chambers Complete	Jun-01
		HCAL	9 Finish Production Brass Wedges @ CERN	Dec-01
		HCAL	10 Finish Production Optical System @ CERN	Dec-01
		HCAL	11 HCAL Electronics Complete @ CERN	Jan-02
		ECAL	12 Final Prod ECAL Serializer Wafer	Feb-02
		TriDAS	13 Trigger MPC Board Assembly Complete	Jan-03
		Inst	14 Start CMS Installation in Pit	Jan-03
		CP	15 HE+YE+ connect	Jan-03
		CP	16 HB in Vacuum Tank Test	Mar-03
		CP	17 HE-YE- connect	May-03
		EMU	18 1st Half CSC Assembly at CERN Complete	Jul-03
		TriDAS	19 DAQ Event Manager Boards Complete	Aug-03
		CP	20 Magnet Full Field Test Completed @ CERN	Sep-03
		Inst	21 BO Underground Counting House	Sep-03
		ECAL	22 Complete Production of APDs	Sep-03
		Inst	23 Install Magnet in Collision Hall	Oct-03
		EMU	24 All ME234/2 Assembled & Tested	Oct-03
		EMU	25 EMU Electronics Complete	Dec-03
		ECAL	26 Forward Pixels Shipped to CERN	Sep-04
		All	27 US CMS Construction Complete	Sep-04

* JOG - Joint Oversight Group Controlled Milestones

** APM / DD - Agency Project Manager / Fermilab Deputy Director Controlled Milestones

*** See Acronym List

Appendix 4: US CMS Cost Baseline

WBS Number	Description	Cost (k$)
1	Endcap Muon	$26,551
2	Hadron Calorimeter	$30,255
3	Trigger and Data Acquisition	$12,393
4	Electromagnetic Calorimeter	$7,728
5	Forward Pixels	$5,208
6	Common Projects	$23,714
7	Project Office	$5,738
	Subtotal	**$111,587**
	Contingency	$48,743
	FY 96 & FY 97	$6,920
	Total Project Cost	**$167,250**

Appendix 5: US CMS Major Procurements

1. Endcap Muon

ID	WBS	Item	Cost K$	Start Date*	Finish Date**	Institution	Planned Funding
114	1.1.3.2.4.1	FY1998 (15 ME23/2)	109,605	01-Jul-98	22-Sep-98	Fermilab	DOE
86	1.1.1.4.8	Tooling Upgrade Development	129,808	06-Jan-99	19-Dec-01	Fermilab	DOE
179	1.1.3.3.4.1	FY1999 (23 ME23/2 chambers)	168,866	06-Jan-99	29-Jun-99	Fermilab	DOE
115	1.1.3.2.4.2	FY1999 (29 ME23/2, 19 ME ME23/1, 37 ME1/23)	426,161	01-Jul-99	22-Sep-99	Fermilab	DOE
890	1.2.4.3.1.1	Procure FPGA/EPROM set #1	112,210	01-Oct-99	18-Feb-00	Rice	DOE
633	1.2.1.3.2.4.1	Procure Latch ASIC Set #1	114,935	01-Nov-99	20-Mar-00	UCLA	DOE
769	1.2.2.3.2.2.1	Procure Latch ASIC Set #1	108,203	01-Nov-99	20-Mar-00	UCLA	DOE
180	1.1.3.3.4.2	FY2000 (50 ME23/2 chambers)	367,100	06-Jan-00	28-Jun-00	Fermilab	DOE
332	1.1.3.4.6.1.1	19 ME23/1 worth of materials	108,167	06-Jan-00	20-Dec-00	Fermilab	DOE
336	1.1.3.4.6.2.1	37 ME1/23 worth of materials	178,747	06-Jan-00	20-Dec-00	Fermilab	DOE
977	1.6.2.1.3	procure CU pads	137,000	06-Jan-00	01-Mar-00	Wisconsin	DOE
116	1.1.3.2.4.3	FY2000 (42 ME23/2, 19 ME ME23/1, 37 ME1/23)	521,152	03-Jul-00	22-Sep-00	Fermilab	DOE
654	1.2.1.3.3.2	Procure PC Board Set #1	188,270	15-Sep-00	07-Dec-00	Ohio State	DOE
782	1.2.2.3.3.2	Procure PC Board Set #1	160,736	18-Sep-00	08-Dec-00	UCLA/CMU	DOE
891	1.2.4.3.1.2	Procure FPGA/EPROM set #2	112,210	02-Oct-00	16-Feb-01	Rice	DOE
181	1.1.3.3.4.3	FY2001 (50 ME234/2 chambers)	367,100	04-Jan-01	27-Jun-01	Fermilab	DOE
333	1.1.3.4.6.1.2	19 ME23/1 worth of materials	108,167	04-Jan-01	19-Dec-01	Fermilab	DOE
337	1.1.3.4.6.2.2	37 ME1/23 worth of materials	178,747	04-Jan-01	19-Dec-01	Fermilab	DOE
970	1.6.1.2	procure parts	160,000	02-Apr-01	01-Jul-01	Wisconsin	DOE
655	1.2.1.3.3.3	Procure PC Board Set #2	188,270	25-Jun-01	14-Sep-01	Ohio State	DOE
783	1.2.2.3.3.3	Procure PC Board Set #2	160,736	26-Jun-01	17-Sep-01	UCLA/CMU	DOE
117	1.1.3.2.4.4	FY2001 (42 ME23/2, 19 ME ME23/1, 37 ME1/23)	521,152	02-Jul-01	21-Sep-01	Fermilab	DOE
955	1.4.1.2	procure fixture parts	100,000	02-Jul-01	01-Oct-01	Wisconsin	DOE
892	1.2.4.3.1.3	Procure FPGA/EPROM set #3	112,210	01-Oct-01	18-Feb-02	Rice	DOE
182	1.1.3.3.4.4	FY2002 (25 ME234/2 chambers)	183,550	04-Jan-02	27-Jun-02	Fermilab	DOE
334	1.1.3.4.6.1.3	38 ME23/1 worth of materials	216,334	04-Jan-02	19-Dec-02	Fermilab	DOE
338	1.1.3.4.6.2.3	74 ME1/23 worth of materials	357,494	04-Jan-02	19-Dec-02	Fermilab	DOE
866	1.2.3.3.3	FED/DDU (Interface in DAQ crate)	166,382	01-Apr-02	21-Jan-04	Ohio State	DOE
656	1.2.1.3.3.4	Procure PC Board Set #3	188,270	24-Jun-02	13-Sep-02	Ohio State	DOE
784	1.2.2.3.3.4	Procure PC Board Set #3	160,736	26-Jun-02	17-Sep-02	UCLA/CMU	DOE
118	1.1.3.2.4.5	FY2002 (20 ME23/2, 19 ME ME23/1, 37 ME1/23)	360,398	01-Jul-02	20-Sep-02	Fermilab	DOE
487	1.1.7.3.1	HV Power Supplies	292,744	06-Jan-03	27-Jun-03	UF	DOE
488	1.1.7.3.2	HV Power Supplies	292,744	07-Jan-04	29-Jun-04	UF	DOE
TOTAL			**33**				

* Start Date: Contract award date.

** Finish Date: Item completed at factory or delivered.

2. Hadron Calorimeter

ID	WBS	Item	Cost K$	Start Date*	Finish Date**	Institution	Planned Funding
845	2.1.10.1.5.1	PPP1 M&S Funding (FY97)	199,480	30-Sep-97	30-Sep-97	FNAL	DOE
883	2.1.10.1.9.2	Motion Table M&S	240,000	30-Jan-98	26-Feb-98	Roch	DOE
858	2.1.10.1.6.3	Fabricate, Machine, and Assemble PPP2	196,680	16-Nov-98	01-Mar-99	FNAL	DOE
176	2.1.2.2.2.1	3.7 mm Scintillator (m**2)	205,823	06-Jan-99	02-Feb-99	Roch	DOE
10	2.1.1.2.1	Fabrication and Machining for HB-1 (P1-18)	1,464,586	01-Oct-99	31-Mar-00	FNAL	DOE
369	2.1.4.3	HPD19 (HB-1)	180,000	01-Oct-99	07-Apr-00	Notre Dame	NSF
12	2.1.1.2.3	Rail Support Plunger System (4 wedges total)	200,000	13-Oct-99	12-Apr-00	FNAL	DOE
1378	2.3.2.2.1	3.7 mm Scintillator (m**2)	254,800	14-Oct-99	10-Nov-99	Roch	DOE
1476	2.3.4.2	HPD19 HE	270,000	10-Apr-00	26-Jan-01	Notre Dame	NSF
227	2.1.2.3.2.1	3.7 mm Scintillator (m**2)	205,823	01-Jun-00	28-Jun-00	Roch	DOE
19	2.1.1.3.1	Fabrication and Machining for HB+1 (P19-36)	1,464,586	02-Oct-00	02-Mar-01	FNAL	DOE
15	2.1.1.2.6	Disassemble and Ship HB-1 Wedges and Barrel Cradle	2,196,879	04-Oct-00	14-Nov-00	FNAL	DOE
427	2.1.5.2.1.6	Channel Control ASIC Engineering Run	125,000	05-Oct-00	29-Nov-00	FNAL	DOE
459	2.1.5.3.2.1	Optical Transmitter Acquisition	164,160	18-Jan-01	14-Feb-01	FNAL	DOE
380	2.1.4.10	HPD19 (HB+1)	180,000	29-Jan-01	15-Jun-01	Notre Dame	NSF
2045	2.5.2.4.1.1.1.2.1	QP Fibers - US	166,600	01-May-01	20-Aug-01	Fairfield	DOE
2072	2.5.2.4.1.2.1.2.1	QP Fibers - US	166,600	01-May-01	20-Aug-01	Fairfield	DOE
1148	2.2.4.8	HPD19: HOB+-	240,000	03-Sep-01	01-Apr-02	Notre Dame	NSF
21	2.1.1.3.3	Disassemble Wedges and Ship HB+1 and Barrel Cradle	2,196,879	13-Sep-01	24-Oct-01	FNAL	DOE
2101	2.5.2.4.2.1.1.2.1	QP Fibers - US	166,600	01-Apr-02	19-Jul-02	Fairfield	DOE
2128	2.5.2.4.2.2.1.2.1	QP Fibers - US	166,600	01-Apr-02	19-Jul-02	Fairfield	DOE
2183	2.5.4.1	Purchase PMTs	545,325	01-May-02	19-Feb-03	Nebr	NSF
619	2.1.7.1.2.1	VME Readout Module Acquisition	341,504	01-Oct-02	08-Apr-03	FNAL	DOE
638	2.1.7.2.4.1	VME Transition Module Acquisition	138,736	01-Oct-02	08-Apr-03	FNAL	DOE
1217	2.2.7.1.1	VME Readout Module Acquisition	133,632	01-Oct-02	08-Apr-03	FNAL	DOE
1554	2.3.7.1.1	VME Readout Module Acquisition	237,568	01-Oct-02	08-Apr-03	FNAL	DOE
2343	2.5.7.1.1	VME Readout Module Acquisition	118,784	01-Oct-02	28-Oct-02	FNAL	DOE
2389	2.5.8.1.6.1	High Voltage Module Acquisition	118,980	11-Feb-04	09-Mar-04	Fairfield	DOE
TOTAL			**28**				

* Start Date: Contract award date.

** Finish Date: Item completed at factory or delivered.

3. Trigger and Data Acquisition

ID	WBS	Item	Cost K$	Start Date*	Finish Date**	Institution	Planned Funding
267	3.1.2.8.2.2	RC Parts	1,187,200	02-Jul-01	28-Jan-02	WISC	DOE
268	3.1.2.8.2.3	RC Board	128,000	27-Aug-01	28-Jan-02	WISC	DOE
276	3.1.2.9.2.2	EIC Parts	478,400	03-Sep-01	01-Apr-02	WISC	DOE
270	3.1.2.8.2.5	16 RC Spares/Preprod	141,920	17-Sep-01	20-May-02	WISC	DOE
269	3.1.2.8.2.4	RC Assembly	104,000	29-Jan-02	20-May-02	WISC	DOE
188	3.2.5.4.3	FUS Order 1	172,800	03-Jul-02	08-Jan-03	UCLA	NSF
202	3.2.5.5.3	Crates order 1	102,400	03-Jul-02	24-Sep-02	MIT	DOE
206	3.2.5.5.7	Crates order 2	204,800	06-Nov-02	12-Feb-03	MIT	DOE
146	3.2.5.1.3	FUI Order 1	243,200	13-Nov-02	21-May-03	MIT	DOE
160	3.2.5.2.3	FUO Order 1	166,400	13-Nov-02	21-May-03	UCSD	DOE
174	3.2.5.3.3	FUM Order 1	192,000	13-Nov-02	21-May-03	UCSD	DOE
192	3.2.5.4.7	FUS Order 2	345,600	04-Apr-03	25-Sep-03	UCLA	NSF
164	3.2.5.2.7	FUO Order 2	332,800	27-May-03	18-Nov-03	UCSD	DOE
178	3.2.5.3.7	FUM Order 2	384,000	27-May-03	18-Nov-03	UCSD	DOE
150	3.2.5.1.7	FUI Order 2	486,400	21-Aug-03	27-Feb-04	MIT	DOE
TOTAL			**15**				

* Start Date: Contract award date.

** Finish Date: Item completed at factory or delivered.

4. Electromagnetic Calorimeter

ID	WBS	Item	Cost K$	Start Date*	Finish Date**	Institution	Planned Funding
61	4.1.3.1	Manufacture APD's	100,000	20-Oct-97	23-Mar-98	Minnesota	DOE
87	4.1.4.1	Process Engineering	120,000	13-Jul-98	25-Jan-99	Minnesota	DOE
250	4.2.5.2	Package Production Barrel	220,320	28-Jul-98	14-Dec-98	Princeton	DOE
175	4.2.1.20	FPU v3 DMILL	125,000	01-Oct-98	18-Jan-99	Princeton	DOE
253	4.2.5.5	Readout Card Production Barrel	372,000	11-Nov-98	01-Sep-99	Princeton	DOE
274	4.3.3.1.2	Laser Purchasing	170,000	12-Nov-98	15-Apr-99	Caltech	DOE
91	4.1.4.3	Fabricate 2000 APD's	125,000	09-Mar-99	15-Nov-99	Northeastern	NSF
119	4.1.6.2.1	Procure 9,000 APD's	379,827	01-Oct-99	29-Sep-00	Northeastern	NSF
182	4.2.1.26.1	FY00 purchase	243,600	01-Oct-99	04-Feb-00	Princeton	DOE
223	4.2.4.2.12.1	FY00 Production	434,070	19-Jan-00	06-Jun-00	Princeton	DOE
120	4.1.6.2.2	Procure 9,000 APD's	379,827	02-Oct-00	28-Sep-01	Northeastern	NSF
185	4.2.1.26.4	FY01 purchase	243,600	02-Oct-00	27-Oct-00	Princeton	DOE
226	4.2.4.2.12.4	FY01 Production	434,070	02-Oct-00	02-Mar-01	Princeton	DOE
188	4.2.1.26.7	FY02 purchase	243,960	01-Oct-01	26-Oct-01	Princeton	DOE
229	4.2.4.2.12.7	FY02 Production	434,070	01-Oct-01	04-Mar-02	Princeton	DOE
121	4.1.6.2.3	Procure 9,000 APD's	379,827	11-Oct-01	30-Sep-02	Northeastern	NSF
122	4.1.6.2.4	Procure 9,000 APD's	379,827	01-Oct-02	18-Sep-03	Northeastern	NSF
TOTAL			**17**				

* Start Date: Contract award date.

** Finish Date: Item completed at factory or delivered.

5. Forward Pixels

ID	WBS	Item	Cost K$	Start Date*	Finish Date**	Institution	Planned Funding
93	5.1.3.1.3.1	procurement	184800	27-Sep-01	23-May-02	JHU	NSF
230	5.2.3.3	Production	300000	14-May-02	15-Apr-03	JHU	NSF
24	5.1.1.2.1	Production	600000	15-May-02	17-Oct-02	JHU	NSF
109	5.1.4.2.1	See e-mail form Jeoff Hall of 980417, included in the BOE folder.	150000	29-Apr-04	01-Aug-04	JHU	NSF
449	5.3.2.2.1.1	refrigerator procured	150000	17-Aug-04	23-Aug-04	Miss.	DOE
TOTAL			**5**				

* Start Date: Contract award date.

** Finish Date: Item completed at factory or delivered.

6. Common Projects

ID	WBS	Item	Cost K$	Start Date*	Finish Date**	Inst.	Planned Funding
10	6.1.5.2	End Cap Iron Return Yoke 98	2,740,000	01-Oct-97	30-Sep-98	Fermilab	DOE
24	6.2.5.2	End Cap Iron Return Yoke 98	1,580,000	01-Oct-97	30-Sep-98	Wisconsin	DOE
11	6.1.5.3	End Cap Iron Return Yoke 99	2,520,800	01-Oct-98	01-Nov-99	Fermilab	DOE
25	6.2.5.3	End Cap Iron Return Yoke 99	3,646,000	01-Oct-98	30-Sep-99	Wisconsin	DOE
26	6.2.5.4	End Cap Iron Return Yoke 00	3,192,000	01-Oct-99	29-Sep-00	Wisconsin	DOE
12	6.1.5.4	End Cap Iron Return Yoke 00	2,723,200	01-Nov-99	30-Nov-00	Fermilab	DOE
27	6.2.5.5	End Cap Iron Return Yoke 01	2,799,000	02-Oct-00	28-Sep-01	Wisconsin	DOE
14	6.1.5.6	End Cap Iron Return Yoke 02	119,600	22-Jun-01	24-Jul-02	Fermilab	DOE
28	6.2.5.6	End Cap Iron Return Yoke 02	1,692,000	01-Oct-01	30-Sep-02	Wisconsin	DOE
29	6.2.5.7	End Cap Iron Return Yoke 03	338,000	01-Oct-02	30-Sep-03	Wisconsin	DOE
30	6.2.5.8	End Cap Iron Return Yoke 04	338,000	01-Oct-03	30-Sep-04	Wisconsin	DOE
TOTAL			**11**				

* Start Date: Contract award date.

** Finish Date: Item completed at factory or delivered.

Appendix 6: Proposed US CMS Project Management Change Control Thresholds

	Level 0	Level 1	Level 2	Level 3a	Level 3b
	DOE Director of Energy Research /NSF Director of Mathematical and Physical Sciences	DOE/NSF Joint Oversight Group	DOE/NSF (Agency) Project Manager	Fermilab Deputy Director	US CMS Technical Director & Construction Project Manager
Technical	Changes that require modification to the US/CERN Agreement and Experiments Protocol	Approve the technical baseline as described in Appendix 2: US CMS Technical Baseline Document.	Significant changes to the technical baseline as described in Appendix 2: US CMS Technical Baseline Document.	Any change in scope that has a significant impact on the physics performance of a sub-detector, including trade-offs among subdetectors Significant changes in scope or detailed design of subdetectors.	Any change in scope or physics performance of a subdetector, including trade-offs among subdetectors. Changes in scope or detailed design of subdetectors as documented in the Design Handbook.
Schedule	Changes that require modification to the US/CERN Agreement and Experiments Protocol.	Greater than six month change in a Level 1 milestone. [Appendix 3: US CMS Baseline Schedule.]	Greater than three month change in a Level 2 milestone. [Appendix 3: US CMS Baseline Schedule.]	Greater than three month change in a Level 2 milestone. [Appendix 3: US CMS Baseline Schedule.]	Greater than a one month change in a Level 2 milestone. [Appendix 3: US CMS Baseline Schedule.] Greater than one month change to milestones defined by the CPM and TD.
Cost	Changes that require modification to the US/CERN Agreement and Experiments Protocol.	Any change to the US CMS Total Project Cost (TPC).	Cumulative changes greater than $2.5 million to the US CMS cost baseline at WBS Level 2. [Appendix 4: US CMS Cost Baseline.]	Cumulative changes greater than $1.0 million to the US CMS cost baseline at WBS Level 2. [Appendix 4: US CMS Cost Baseline.]	Cumulative changes in the cost baseline of $100 thousand at WBS Level 2. [US CMS Cost Estimate dated May 1998.]